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Assessment of water quality under national highway expansion activity in Himachal Pradesh

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Abstract
Water is one of the precious natural resource and is essential for the survival of living organisms. However due to developmental activities its quality is deteriorating and has now become a major environmental challenge. Therefore a study was conducted to assess the spatial and temporal variation in surface and ground water quality of the sources falling around national highway. In order to conduct the study water sources falling within distance 0-500 m and greater than 500 m from the expansion activities and seasonal effect during pre-monsoon, monsoon and post monsoon months were considered. The parameters selected were pH, EC, turbidity, TDS, BOD, COD, Cl^- and NO_3^-. The results revealed that all the parameters were observed to be significant with spatial and temporal variation for surface and ground water sources near the highway expansion activities. However, all the water parameters were within permissible limits as prescribed by ICMR, except for COD which ranged from 16.31-22.69 mg l^{-1} and 12.82-16.87 mg l^{-1} for surface and ground water sources. The highest value of 20.30 mg l^{-1} was observed within 0-500 m distance in surface water which was significantly higher than the prescribed value. Also, seasonal effect on water properties was observed significant, especially in premonsoon as compared to monsoon and post monsoon. Therefore study concluded that highway expansion activities had started impacting the surface and ground water quality. Henceforth, further surveillance for quality assessment of water sources near highway activities is need of the hour.

Keywords: Physico-chemical properties, seasonal variation, surface and ground water sources, water quality

Introduction
Water is a valuable natural resource and is the basic need without which life does not exist. Also, safe water is a precondition for health and development. However, increasing population, urbanization and modernization in developing countries has created a significant risk on water quality (Rana *et al*., 2016) [24]. Especially, impact of highway construction activities had created a significant threat on surface and ground water quality (Chen *et al*., 2009[8]; Shridharan and Nathan, 2017) [27]. The source of water quality degradation near construction activities primarily includes soil erosion, diesel and oil, construction debris and dirt on impervious road surfaces (Armah *et al*., 2010) [5]. Pollutants generated from these sources are added to adjacent water bodies through both direct discharge by workers at the sites and as well as non-direct discharge with the runoff water leading to physical, chemical and biological degradation of their quality (Abewickrema *et al*., 2013; Wang *et al*., 2013; Yew and Makowski, 1989) [31, 31 33].
A number of studies have focused on sources of pollutants in road runoff such as vehicular pollutants, atmospheric deposition, metals, wear and tear of vehicle brakes and tyres, oil and grease, chemical and other hazardous particulates and later on removed by rainfall due to runoff and ultimately reaches to the surface and ground water bodies, degrade the quality and causing health hazards to all living organisms (Hewitt and Rashed, 1992 [17]; Barbosa *et al*., 2012 [6]; Yannopoulos *et al*., 2013 [32]. However, information related to quantify the effects of road construction on water quality is relatively scarce. To a certain extent, seasons has been shown to correlate with the mobility of atmospheric pollutants especially in premonsoon season due to high temperature and increased evaporation and particularly in monsoon months since washing off the pollutants from road surfaces to adjoining water sources to construction activities (Chow *et al*., 2013; Shen *et al*., 2016) [26, 9].

In this context, we studied the effect of construction of highways on water quality in Himachal Pradesh. Specifically, the objectives of this study were as follow: (1) to identify the effect of spatial variation associated with road pollutants on water quality, (2) to characterize the effect of construction activities on adjoining surface and ground water sources, and (3) to explore the relationship between seasons and water quality. The results of this study may help to know the deterioration level of water quality due to road construction activities.

Material and Methods

A. Study Site and climate

The effect of expansion activities of National Highway- 21 (now NH-154) Kiratpur - Nerchowk Expressway on water quality was assessed during the year 2016 and 2017 in the Department of Environmental Science, YS Parmar University of Horticulture and Forestry, Nauni, Solan. In order to assess the impact a detailed survey was conducted and a uniform stretch of the highway from Garamoura in Bilaspur to Nerchowk in Mandi district of Himachal Pradesh situated between North latitude of 31º21’64" to 31º38’56" and East longitude of 76º56’77" to 76º46’46" was selected.

The study area experiences sub-tropical climate and there is a considerable variation in the seasonal temperature. In general, May-June are the hottest months and December-January, are the coldest ones in the region. The average annual rainfall in the region is 1200 mm, the bulk of which is received during monsoon months. The average maximum and minimum temperature varies from 22.50 to 38.77ºC and 2.40 to 20.40ºC.

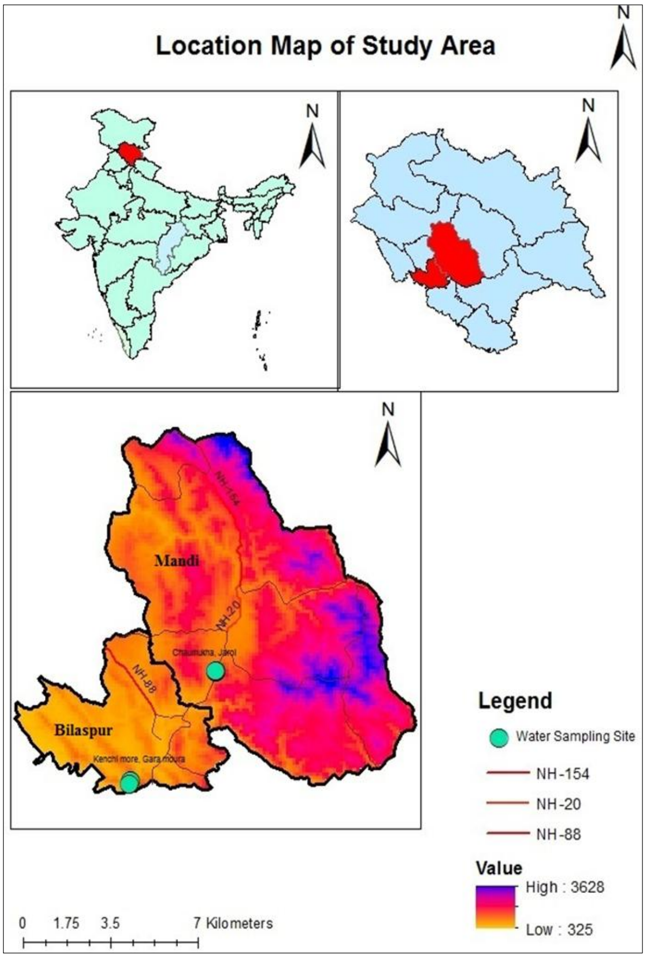

Fig 1: Study Map showing sampling points

Experimental Details

The study site was divided into four equal parts of 10 km stretch each namely, Garamoura and Kenchimore in Bilaspur district at an elevation range from 650-690 m asl and Jarol and Chaumukha in Mandi district from 673-941 m asl.

In order to assess the effect of various construction activities on the water quality, surface and ground water samples were collected at two horizontal distances 0-500 m and >500 m from the centre of the road during premonsoon (May-June), monsoon (July-August) and post monsoon (October-November) seasons. In total there were 12 treatment combinations (2 x 2 x 3) which were replicated four times under Randomized Block Design factorial.

Water Sample Collection

Surface (streams and rivers) and ground (hand pumps, bore wells and tube wells) water samples were collected in plastic bottles of one litre capacity. The surface water samples were collected from 10 to 12 cm below the water surface for detailed chemical 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 (APHA, 2005)[3]. The collected samples were brought to laboratory and analyzed for properties like pH, EC, turbidity, TDS, BOD, COD, Cl^- and NO_3^-.

Water Quality Assessment

The pH of the water samples was determined using microprocessor based pH meter (Model 510 of EIA make). Electrical conductivity and total dissolved solids were measured using microprocessor based conductivity/ TDS meter (Model- 1601 of EIA make). Biochemical Oxygen Demand (BOD) was determined by using BOD-system Oxidirect and chemical oxygen demand (COD) with TR320 Spectroquant after digesting at 148ºC for 120 min. Chloride (Cl^-) and nitrate (NO_3^-) were determined photometrically by using spectroquant pharo 300 (Merck make). The results were compared with permissible limits of WHO, CPCB and ICMR.

Table 1: Permissible limit of water quality parameters for drinking and domestic purpose set by WHO, CPCB and ICMR.

Parameters	CPCB	WHO	ICMR
pH	6.5-8.5	6.5-8.5	7.5-8.5
EC (dS m^{-1})	2000	Not-mentioned	Not-mentioned
Turbidity (NTU)	10	Not-mentioned	Not-mentioned
TDS	500	1000	Not-mentioned
BOD (mg l^{-1})	5	5	Not-mentioned
COD (mg l^{-1})	Not-mentioned	Not-mentioned	20
Chloride (mg l^{-1})	250	250	200
Nitrate (mg l^{-1})	45	45	45

B. Statistical analysis

The data obtained from the analysis of water samples was subjected to statistical analysis using three-way Analysis of Variance (ANOVA) for the Factorial Randomized Block Design and tested at 5% level of significance in the experiment as per the procedure suggested by Gomez and Gomez (1984) [15].

Results and Discussion

The perusal of the data presented in Tables 2a & 2b revealed that pH was significantly influenced spatially during all seasons. Although pH was non-significant with respect to surface and ground water sources and found to range from 7.27 to 7.56 and 7.12 to 7.53. The highest pH of 7.43 was noticed in surface water whereas lowest (7.39) in ground water sources. However, pH of water sources was within permissible limits as prescribed by WHO.

Irrespective of sources, the water samples exhibited highest value of pH (7.48) during pre-monsoon season, which was statistically at par with pH (7.43) during monsoon months and lowest pH of 7.33 was recorded during post monsoon. The maximum value during pre-monsoon season may be due to decreased volume of water by evaporation and minimum in post monsoon seasons may be due to short day length and decrease in evaporation rate. The results are similar as suggested by (Ololade and Ajayi, 2009 [22]; Chauhan and Verma, 2016) [7]. Moreover, the highest value of pH (7.51) was observed at >500 m and lowest value of 7.31 was noticed within distance of 0-500 m. The lowest value of pH at 0-500 m may be due to runoff water from the road consisting high chloride, nitrate salts and transported inorganic particles. The results are in line with the findings of (Klimaszewska *et al*., 2007 [20]; Fronczyk *et al*., 2016) [13].

Also, the interaction between seasons and sources also observed to have significant effect on pH. The highest pH (7.53) was observed in surface water during pre-monsoon season, which was statistically at par with pH (7.47) in ground water sources during monsoon months and lowest pH (7.28) in ground water during post monsoon. The interaction of seasons and distance resulted in a significant influence on pH. The highest pH (7.58) was observed during pre-monsoon months at >500 m and lowest (7.19) during post monsoon within 0-500 m. Also, the distance x source interaction was observed statistically significant with respect to pH. The highest value (7.56) was observed at >500 m in surface water whereas lowest (7.30) within distance 0-500 m in ground water sources. The season x distance x source interaction was found statistically significant with respect to pH. The highest pH (7.71) was observed in surface water at > 500 m during premonsoon season and lowest (7.12) was observed in ground water sources at distance of 0-500 m during post monsoon months.

The scrutiny of data presented in Table 2a & 2b indicated that distance and seasons of the year influenced electrical conductivity (EC) of surface and ground water sources significantly and ranged from 0.53 to 0.82 dSm^{-1} and 0.43 to 0.69 dSm^{-1}, respectively. Also, water sources at registered EC within permissible limits as prescribed by CPCB.

The highest value of EC (0.69 dSm^{-1}) was found in the surface water and lowest (0.59 dSm^{-1}) in ground water sources. The highest value of EC in surface water sources may be due to its more exposure to road expansion activities, which increases chloride, nitrate, sulphate, iron, aluminium ions, as conductivity depends on concentration of ions in solution The present trend is in line with the findings of (Gasim *et al*., 2005 [14]; Polkowska *et al*., 2007 [23]; Harun *et al*., 2010; Doamekpor *et al*., 2016) [11, 16]. Irrespective of sources, the seasons of the year also influenced the EC. The maximum value of EC (0.70 dSm^{-1}) was found during premonsoon season, followed by 0.68 dSm^{-1} in monsoon and minimum during post monsoon months wherein it was 0.54 dSm^{-1}. The highest value of EC in premonsoon months compared to post monsoon was probably due to less availability of water, higher temperature and more evaporation, thereby enhancing the concentration of ions. The results are in consonance with the findings of (Makineci *et al*., 2015) [21]. In addition, the highest value of EC (0.69 dSm^{-1}) was found at 0-500 m near highway expansion activities and lowest value (0.59 dSm^{-1}) at distance of >500 m. Moreover, the highest concentration of EC at 0-500 m distance could be related to disturbance of soil due road construction resulting in the runoff from road and accumulation of salts, particulates or material directly in water sources. The results are in agreement with the findings of (Fronczyk *et al*., 2016) [13].

Also, further perusal of data indicated that interaction between seasons and sources exerted significant influence on EC. The highest value of EC (0.75 dSm^{-1}) was observed in surface water during monsoon season, which was statistically at par with EC in surface water (0.74 dSm^{-1}) during premonsoon month and lowest EC (0.49 dSm^{-1}) in ground water during post monsoon season. The season x distance and distance x sources interactions were found to have non-significant effect on EC of water sources. Moreover, the three way interaction between season x distance x sources was found to be statistically significant with respect to EC. The highest EC (0.82 dSm^{-1}) was found in surface water sources at horizontal distance 0-500 m during monsoon season, which was statistically at par with 0.79 dSm^{-1} in the surface water at distance 0-500 m during premonsoon season and lowest (0.43 dSm^{-1}) was observed in ground water sources at distance of >500 m during post monsoon months.

Table 2a: Spatial and seasonal variations in pH and electrical conductivity of surface and ground water sources.

pH							**EC ($dS\ m^{-1}$)**					
Seasons					**Horizontal Distance**		**Seasons**				**Horizontal Distance**	
Sources	**Premonsoon**	**Monsoon**	**Post monsoon**	**Mean (Sources)**	**0-500 m**	**>500 m**	**Premonsoon**	**Monsoon**	**Post monsoon**	**Mean (Sources)**	**0-500 m**	**>500 m**
Surface water	7.53	7.38	7.37	7.43	7.30	7.56	0.74	0.75	0.58	0.69	0.75	0.64
Ground water	7.43	7.47	7.28	7.39	7.33	7.46	0.65	0.61	0.49	0.59	0.63	0.54
Mean (Seasons)	7.48	7.43	7.33	Mean (Distances)	7.31	7.51	0.70	0.68	0.54	Mean (Distances)	0.69	0.59
0-500 m	7.38	7.36	7.19				0.75	0.73	0.60			
>500 m	7.58	7.50	7.46				0.65	0.64	0.48			

$CD_{0.05}$

Seasons= 0.049	Seasons x Distance= 0.069	Seasons= 0.019	Seasons x Distance= NS
Distance= 0.04	Seasons x Sources= 0.069	Distance= 0.016	Seasons x Sources= 0.027
Sources= NS	Distance x Sources= 0.057	Sources= 0.016	Distance x Sources= NS

Table 2b

Distance	pH						EC (dS m^{-1})					
	Seasons						Seasons					
	Premonsoon		Monsoon		Post monsoon		Premonsoon		Monsoon		Post monsoon	
	Sources						Sources					
	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water
0-500 m	7.35	7.44	7.27	7.48	7.29	7.12	0.79	0.70	0.82	0.64	0.64	0.56
>500 m	7.71	7.51	7.45	7.53	7.49	7.41	0.69	0.61	0.69	0.59	0.53	0.43
Mean	7.53	7.47	7.36	7.50	7.39	7.26	0.74	0.65	0.75	0.61	0.58	0.49

$CD_{0.05}$ Seasons x Distance x Sources= 0.098, Seasons x Distance x Sources= 0.039

The data presented in Table 3a & 3b revealed that turbidity of surface and ground water sources ranged from 2.15 to 5.67 NTU and 1.44 to 3.71 NTU, varied significantly spatially during all the seasons. However, turbidity was within permissible limits as prescribed by WHO. The highest turbidity of 3.75 NTU was found in surface water whereas lowest value (2.78 NTU) in ground water sources. The maximum value of turbidity in surface water sources may be due to soil erosion causing road runoff, which adds suspended particles such as clay, silt and increase the turbidity. The results are in collaboration with findings of (Polkowska *et al*., 2007[23]; Arismendi *et al*., 2107) [4]. Irrespective of sources, the maximum value of turbidity (4.51 NTU) was recorded in the sources falling in the vicinity of construction activities and minimum of 2.02 NTU at >500 m. High turbidity recorded in water sources may be ascribed due to disturbance of soil resulting in the runoff of suspended matter such as clay, silt, organic and inorganic matter in the water surface sources nearby highway. The results are in line with the findings of (Kayhanian *et al*., 2012 [19]; Doamekpor *et al*., 2016) [11]. The seasons of the year also affected the turbidity. The highest value (3.49 NTU) was recorded during monsoon, which was at par with 3.44 NTU in premonsoon and lowest (2.86 NTU) in post monsoon season. The results are in conformity with the findings of Singh *et al*., (2013)[27] who have indicated that high value of turbidity in monsoon season may be due to high clay, silt and their high dilution in the water sources.

Also, further scrutiny of data indicated that the season x source interaction was observed to have significant effect on the turbidity. The highest value of 4.04 NTU was observed in surface water during premonsoon seasons, which was statistically at par with 4.04 NTU in surface water during monsoon months followed by lowest (2.55 NTU) in ground water sources during post monsoon. In addition, the interaction between distance and sources was found to have significant influence on the turbidity. The highest value was 5.35 NTU observed in surface water within 0-500 m and lowest (1.88 NTU) at >500 m in ground water sources. Also, the season x distance interaction was also found to have significant influence on turbidity. The highest value (4.67 NTU) was observed at 0-500 m during premonsoon season, which was at par with 4.64 NTU at 0-500 m during monsoon months and lowest value of 1.49 NTU at >500 m during post monsoon. Moreover, the season x distance x sources interaction was found statistically significant with respect to turbidity. The highest value of turbidity 5.67 NTU was observed in surface water sources at distance 0-500 m during premonsoon season, which was at par with 5.56 NTU in surface water sources within 0-500 m distance during monsoon months and lowest (1.44 NTU) was observed in ground water at >500 m during post monsoon which was at par with 1.55 NTU in surface water at >500 m during post monsoon.

The perusal of data in Table 3a & 3b presented that distance and seasons of the year influenced total dissolved solids (TDS) of surface and ground water sources significantly and ranged from 141.52 to 241.71 mg l^{-1}. Also, water sources registered TDS within permissible limits as prescribed by WHO.

The highest value of TDS (157.04 mg l^{-1}) was found in surface water and lowest (123.82 mg l^{-1}) in ground water sources. Higher content of TDS in surface water sources may be due to surface runoff from the road construction and expansion activities. The present trend is in line with the findings of (Polkowska *et al*., 2007; Kayhanian *et al*., 2012) [,13 19]. Irrespective of sources, the highest value of TDS (198.22 mg l^{-1}) was recorded with 0-500 m near highway construction activities and lowest value of 82.64 mg l^{-1} at >500 m. The maximum value of TDS in water sources adjoining highway, may be due to presence of road dirt, suspended matter and dissolved mineral which were washed off from road surface. The results are in agreement with similar findings of (Al-Badaii *et al*., 2013 [2]; Doamekpor *et al*., 2016) [11]. Also, the highest value of TDS was recorded during monsoon seasons (150.94 mg l^{-1}), followed by 141.18 mg l^{-1} in premonsoon months and lowest (129.16 mg l^{-1}) in post monsoon season.

Further, the data revealed that the interaction between seasons and sources was found to have significant effect on TDS. The maximum content of 170.26 mg l^{-1} was observed in surface water during monsoon whereas minimum (116.80 mg l^{-1}) in ground water sources during post monsoon season. The distance x sources interaction was also observed to have significant influence on TDS. The highest value of 221.62 mg l^{-1} was observed in surface water sources within 0-500 m and lowest (72.80 mg l^{-1}) in ground water at >500 m. The season x distance interaction was also found to have significant influence on TDS. Highest value of TDS (214.51 mg l^{-1}) was observed within 0-500 m during monsoon seasons and lowest (80.26 mg l^{-1}) at >500 m distance during post monsoon months which was at par with 80.28 mg l^{-1} during premonsoon season at distance of >500 m. Moreover, the three way interaction season x distance x source was found statistically significant with respect to TDS. The highest value of 241.71 mg l^{-1} was observed in surface water at distance 0-500 m during monsoon whereas minimum (67.55 mg l^{-1}) was observed in ground water sources at >500 m during premonsoon months.

Table 3: Spatial and seasonal variations in turbidity and total dissolved solids of surface and ground water sources.

Turbidity (NTU)							Total dissolved solids (mg l^{-1})					
Seasons					Horizontal Distance		Seasons				Horizontal Distance	
Sources	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m
Surface Water	4.04	4.04	3.17	3.75	5.35	2.15	159.35	170.26	141.52	157.04	221.62	92.47
Ground Water	2.85	2.94	2.55	2.78	3.68	1.88	123.02	131.62	116.80	123.82	174.83	72.80
Mean (Seasons)	3.44	3.49	2.86	Mean (Distances)	4.51	2.02	141.18	150.94	129.16	Mean (Distances)	198.22	82.64
0-500 m	4.67	4.64	4.24				202.09	214.51	178.06			
>500 m	2.22	2.34	1.49				80.28	87.37	80.26			

$CD_{0.05}$

Seasons= 0.057	Seasons x Distance= 0.081	Seasons= 0473	Seasons x Distance= 0.669
Distance= 0.047	Seasons x Sources= 0.081	Distance= 0.386	Seasons x Sources= 0.669
Sources= 0.047	Distance x Sources= 0.066	Sources= 0.386	Distance x Sources= 0.546

Table 3(b)

Turbidity (NTU)						Total dissolved solids (mg l^{-1})						
Distance	Seasons					Seasons						
	Premonsoon		Monsoon		Post monsoon	Premonsoon		Monsoon		Post monsoon		
	Sources					Sources						
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
0-500 m	5.67	3.66	5.57	3.71	4.80	3.67	225.69	178.50	241.71	187.32	197.45	158.67
>500 m	2.41	2.04	2.51	2.17	1.54	1.44	93.00	67.55	98.81	75.93	85.59	74.93
Mean	4.04	2.85	4.04	2.94	3.17	2.55	159.35	123.02	170.26	131.62	141.52	116.80

$CD_{0.05}$ Seasons x Distance x Sources= 0.114 Seasons x Distance x Sources= 0.946

Table 4(a): Spatial and seasonal variations in BOD and COD of surface and ground water sources due to National Highway expansion activities

BOD (mg l^{-1})							COD (mg l^{-1})					
Sources	Seasons				Horizontal Distance		Seasons				Horizontal Distance	
	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m
Surface Water	2.13	2.02	1.69	1.94	3.01	0.88	17.14	19.79	16.62	17.85	20.30	15.41
Ground Water	1.62	1.45	0.97	1.34	1.88	0.81	15.02	16.87	13.90	15.26	16.31	14.22
Mean (Seasons)	1.87	1.73	1.33	Mean (Distances)	2.44	1.34	16.08	18.33	15.26	Mean (Distances)	18.30	14.81
0-500 m	2.74	2.56	2.02				17.44	20.35	17.11			
>500 m	1.00	0.90	0.64				14.72	16.32	13.41			

$CD_{0.05}$

Seasons= 0.061	Seasons x Distance= 0.086	Seasons= 0.429	Seasons x Distance= 0.606
Distance= 0.050	Seasons x Sources= 0.086	Distance= 0.350	Seasons x Sources= NS
Sources= 0.050	Distance x Sources= 0.070	Sources= 0.350	Distance x Sources= 0.495

Table 4(b)

BOD (mg l^{-1})							COD (mg l^{-1})					
Distance	Seasons						Seasons					
	Premonsoon		Monsoon		Post monsoon		Premonsoon		Monsoon		Post monsoon	
	Sources						Sources					
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
0-500 m	3.23	1.02	3.07	0.96	2.71	0.67	18.95	15.94	22.69	18.01	19.25	14.98
>500 m	2.26	0.98	2.05	0.84	1.32	0.62	15.34	14.10	16.90	15.74	14.00	12.82
Mean	2.74	1.00	2.56	0.90	2.02	0.64	17.14	15.02	19.79	16.87	16.62	13.90

$CD_{.05}$, Seasons x Distance x Sources= 0.122, Seasons x Distance x Sources= NS

Table 5(a): Spatial and seasonal variations in Chloride and Nitrate of surface and ground water sources due to National Highway expansion activities.

Cl^- (mg l^{-1})							NO_3^- (mg l^{-1})					
Sources	Seasons				Horizontal Distance		Seasons				Horizontal Distance	
	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m	Premonsoon	Monsoon	Post monsoon	Mean (Sources)	0-500 m	>500 m
Surface Water	18.37	16.47	14.39	16.41	18.40	14.43	2.76	3.44	2.03	2.74	3.08	2.40
Ground Water	13.84	13.40	12.75	13.33	13.98	12.68	2.12	3.03	1.64	2.26	2.48	2.05

Mean (Seasons)	16.10	14.93	13.57	Mean (Distances)	16.19	13.56	2.44	3.23	1.83	Mean (Distances)	2.78	2.23
0-500 m	17.92	16.06	14.58				2.78	3.47	2.07			
>500 m	14.29	13.81	12.57				2.09	2.99	1.59			

$CD_{0.05}$
Seasons= 0.510 Seasons x Distance= 0.721
Distance= 0.416 Seasons x Sources= 0.721
Sources= 0.416 Distance x Sources= 0.588

Seasons= 0.095 Seasons x Distance= 0.134
Distance= 0.077 Seasons x Sources= 0.134
Sources= 0.077 Distance x Sources= 0.110

Table 5(b)

Distance	Cl^- (mg l^{-1})						NO_3^- (mg l^{-1})					
	Seasons						Seasons					
	Premonsoon		Monsoon		Post monsoon		Premonsoon		Monsoon		Post monsoon	
	Sources						Sources					
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
0-500 m	21.67	14.18	17.93	14.18	15.59	13.57	3.12	2.45	3.70	3.25	2.41	1.73
>500 m	15.08	13.49	15.01	12.61	13.20	11.94	2.39	1.79	3.18	2.81	1.64	1.55
Mean	18.37	13.84	16.47	13.40	14.39	12.75	2.76	2.12	3.44	3.03	2.03	1.64

$CD_{0.05,}$ Seasons x Distance x Sources= 1.019, Seasons x Distance x Sources= 0.190

The data pertaining to the effect of highway expansion activity on water quality parameter, viz. biochemical oxygen demand (BOD) is presented in Table 4a and 4b indicated that distance and seasons of the year influenced BOD of surface and ground water sources significantly and ranged from 1.69 to 3.23 mg l^{-1} and 0.62 to 1.62 mg l^{-1}. However, water sources registered BOD within permissible limits as prescribed by WHO.

The highest BOD of 1.94 mg l^{-1} was observed in surface water and lowest in ground water sources (1.34 mg l^{-1}). The highest value of BOD in surface water sources may be due to its more exposure to road expansion activities and also BOD concentration continuously increases in surface water because of plant decaying process and other contributors that increase the total nutrient in water sources such as fertilizers, construction effluent. The results are in line with similar findings of (Polkowska *et al*., 2007[23]; Rosli *et al*., 2010) [25]. Irrespective of sources, the maximum BOD of 2.44 mg l^{-1} was recorded within 0-500 m, whereas the minimum of 1.34 mg l^{-1} at >500 m. High BOD may be due to runoff from the highway and road construction activities. The results are in line with findings of (Abewickrema *et al*., 2013) [1]. Moreover, the highest value of 1.87 mg l^{-1} was observed during pre-monsoon followed by 1.73 mg l^{-1} monsoon months and lowest (1.33 mg l^{-1}) in the post monsoon season. The highest value of BOD during pre-monsoon season can be ascribed to decreased oxygen concentration with high biological activity at elevated temperatures. The present trend of seasonal variations has also been observed by (Olollade and Ajayi, 2009) [22].

The results further indicated that the interaction between seasons and sources was found to have significant influence on BOD. The highest value of BOD observed was 2.13 mg l^{-1} during pre-monsoon in surface water, which was at par with 2.02 mg l^{-1} during monsoon season in the surface water sources and lowest (0.97 mg l^{-1}) during post monsoon season in the ground water sources. The distance x sources interaction was also found to have significant influence on the BOD. The highest value of 3.01 mg l^{-1} was observed within distance 0-500 m in surface water and lowest value (0.81 mg l^{-1}) at > 500 m in ground water sources. In addition, the season x distance interaction was also found to have significant influence on BOD. The highest BOD (2.74 mg l^{-1}) was observed at distance 0-500 m during pre-monsoon and lowest (0.64 mg l^{-1}) at > 500 m during post monsoon season. Moreover, the seasons x distance x sources interaction was found to be statistically significant with respect to BOD. The highest value of 3.23 mg l^{-1} was recorded in surface water sources within 0-500 m distance during premonsoon season and lowest (0.84 mg l^{-1}) was recorded in ground water at distance of >500m during post monsoon months which was at par with 0.84 mg l^{-1} in the ground water at distance >500 m, during monsoon season.

The scrutiny of data presented in Table 4a and 4b revealed that distance and seasons of the year influenced chemical oxygen demand (COD) of surface and ground water sources significantly and ranged from 16.31 to 22.69 mg l^{-1} and 12.82 to 16.87 mg l^{-1}

The highest value of COD (18.30 mg l^{-1}) was recorded within distance of 0-500 m and lowest value 14.81 mg l^{-1} at >500 m. The results are in agreement with the findings of Vieira *et al*. (2013) [30] who reported that maximum COD may be due the pollutants generated by the traffic pollution and road construction. Irrespective of sources, highest COD value of 17.85 mg l^{-1} was observed in surface water and lowest (15.26 mg l^{-1}) in ground water sources. The highest value of COD in surface water sources may be due to presence of inorganic and organic non-biodegradable content of pollutants generated by the traffic pollution and road construction activities. The results are in line with findings of (Polkowska *et al*., 2007[23]; Sirohi *et al*., 2014) [29]. Also, the maximum COD of 18.33 mg l^{-1} was observed during monsoon season, followed by 16.08 mg l^{-1} during pre-monsoon months and lowest (15.26 mg l^{-1}) in the post monsoon. The highest value of COD during monsoon may be due to more dilution of road pollutants in water sources. Similar trend of seasonal variation of COD was observed by (Ibraheem *et al*., 2015) [18].

Further, the data indicated that the distance x sources interaction was found to have significant influence on COD. The highest value of 20.30 mg l^{-1} was observed at 0-500 m in surface water which was found above permissible limits as prescribed by ICMR whereas lowest value (14.22 mg l^{-1}) at > 500 m in ground water samples. The results are in agreement with the findings of (Forman and Alexander, 1998 [12]; Vieira *et al*., 2013) [30] who reported that maximum COD in surface water sources nearby highway may be due the runoff of pollutants generated by the traffic pollution and road expansion activities. The seasons x distance interaction was also found to have significant influence on the COD. The highest value of COD observed was 20.35 mg l^{-1} during monsoon season at distance 0-500 m and lowest (13.41 mg l^{-1}) during post monsoon at >500 m. Moreover, the seasons x distance x sources interaction was found to be non-significant with respect to COD of water samples.

The data pertaining to water quality parameter, viz. Chloride (Cl^-) cited in Tables 5a and 5b revealed distance and seasons of the year influenced Cl^- surface and ground water sources significantly and ranged from 14.39 to 21.67 mg l^{-1} and 12.68 to 14.18 mg l^{-1}. However, water sources registered Cl^- within permissible limits as prescribed by WHO.

The highest value of Cl^- (16.41 mg l^{-1}) was recorded in surface water and lowest (13.33 mg l^{-1}) in ground water sources. The results are consonance with the findings of (Polkowska *et al*., 2007) [23] who have also noticed high content of Cl^- in surface water sources and advocated high increasing road expansion activities as the main cause. Irrespective of sources, the maximum value of Cl^- (16.10 mg l^{-1}) was observed during premonsoon season followed by monsoon months of 14.93 mg l^{-1} and lowest (13.57 mg l^{-1}) in the post monsoon. The highest Cl^- level during premonsoon may be due to high temperature and evaporation of water from the sources leaving behind salts and ions. The results are in agreement with the findings of (Ololade and Ajayi, 2009) [22]. Also, the highest value of Cl^- (16.19 mg l^{-1}) was recorded within 0-500 m whereas lowest (13.56 mg l^{-1}) at >500 m. The highest value of Cl^- may be due to higher traffic intensity and runoff consisting ions. The results are in line with the findings of (Doamekpor *et al*., 2016[11]; Fronczyk *et al*., 2016) [13].

Further scrutiny of data revealed that the seasons x sources interaction was also found to have significant influence on Cl^-. The highest value of Cl^- 18.37 mg l^{-1} was observed during premonsoon season in surface water, whereas lowest (12.75 mg l^{-1}) during post monsoon in ground water, which was at par with 13.40 mg l^{-1} during monsoon season for ground water sources. The distance x sources interaction was also found to have significant influence on Cl^-. The highest value recorded was 18.40 mg l^{-1} within 0-500 m in surface water and lowest (12.68 mg l^{-1}) at > 500 m in ground water sources. Also, the seasons x distance interaction was also found to have significant influence on Cl^-. The highest value of Cl^- 17.92 mg l^{-1} was observed during premonsoon season at 0-500 m and lowest (12.57 mg l^{-1}) during post monsoon at >500 m. Moreover, the seasons x distance x sources interaction was found to be statistically significant with respect to Cl^-. The highest value (21.67 mg l^{-1}) was recorded in surface water at 0-500 m during premonsoon season and lowest (11.94 mg l^{-1}) was recorded in ground water sources at >500m during post monsoon which was at par with 12.61 mg l^{-1} in the ground water at >500 m, during monsoon season.

The scrutiny of data present in Tables 5a & 5b revealed that distance and seasons of the year influenced nitrate (NO_3^-) of surface and ground water sources significantly and found to range from 2.07 to 3.70 mg l^{-1} and 1.55 to 3.25 mg l^{-1}. However, water sources registered COD within permissible limits as prescribed by WHO.

The highest value of NO_3^- was observed in surface water of 2.74 mg l^{-1} and lowest in ground water sources (2.26 mg l^{-1}). The highest value of NO_3^- in surface water may be due to its more exposure to road expansion activities and NO_3^- is a naturally occurring form of nitrogen which is very mobile in water (Gasim *et al*., 2005 [14]; Polkowska *et al*. 2007) [23]. The seasons of the year also influenced the NO_3^-. In this part the sources exhibited highest value of NO_3^- (3.23 mg l^{-1}) during monsoon season followed by premonsoon months (2.44 mg l^{-1}) and lowest (1.83 mg l^{-1}) during post monsoon. The similar seasonal trend is also noticed by (Singh *et al*., 2013) [28]. Irrespective of sources and seasons, the highest value of NO_3^- (2.78 mg l^{-1}) was recorded within 0-500 m and lowest value 2.23 mg l^{-1} at >500 m. The highest value of NO_3^- at 0-500 m may be due to deposition of nitrogen oxides from fuel combustion, which might have formed nitric acid (HNO_3), leading to concentrate in water sources, the results are in line with (Dillon and Chanton, 2005 [10]; Fronczyk, *et al*., 2016) [13].

It is further evident from the data that the interaction between seasons and sources resulted in a significant influence on NO_3^-. The highest value of NO_3^- was 3.44 mg l^{-1} during monsoon season in surface water and lowest value of 1.64 mg l^{-1} during post monsoon in ground water sources. The distance x source interaction was also found to have significant influence on NO_3^- in water sources. The highest value of 3.08 mg l^{-1} was observed within 0-500 m in surface water sources and lowest value was 2.05 mg l^{-1} at > 500 m in ground water sources. The seasons x distance interaction was also found to have significant influence on NO_3^-. The highest value of NO_3^- was 3.47 mg l^{-1} during monsoon season at 0-500 m and lowest value of 1.59 mg l^{-1} during post monsoon month at >500 m distance.

The seasons x distance x source interaction was found to be statistically significant with respect to NO_3^-. The highest value (3.70 mg l^{-1}) was recorded in surface water at 0-500 m during monsoon season and lowest value (1.55 mg l^{-1}) was recorded in ground water sources at distance of >50 0m during post monsoon which was at par with 1.73 mg l^{-1} in the ground water sources at distance 0-500 m, during post monsoon.

Table 6: Correlation matrix of water quality parameters

	pH	EC	Turbidity	TDS	BOD	COD	Cl^-	NO_3^-
pH	1							
EC	-0.066	1						
Turbidity	-0.556*	0.741*	1					
TDS	-0.569*	0.664*	0.965*	1				
BOD	-0.467*	0.731*	0.966*	0.956*	1			
COD	-0.356*	0.775*	0.855*	0.823*	0.835*	1		
Cl^-	-0.223	0.733*	0.760*	0.669*	0.743*	0.689*	1	
NO_3^-	0	0.770*	0.623*	0.595*	0.610*	0.817*	0.562*	1

*Significant ay $p \leq 0.05$

Correlation Analysis

The scrutiny of analysis presented in table 6 revealed that pH had significant negative correlation with turbidity, TDS, BOD, COD and Cl^-. Also, there was a significant positive correlation among and between EC, turbidity, TDS, BOD, COD, Cl^- and NO_3^-. While, there was no correlation between pH and NO_3^-Overall analysis stated that each water parameter plays a significant role in the evaluation of water quality.

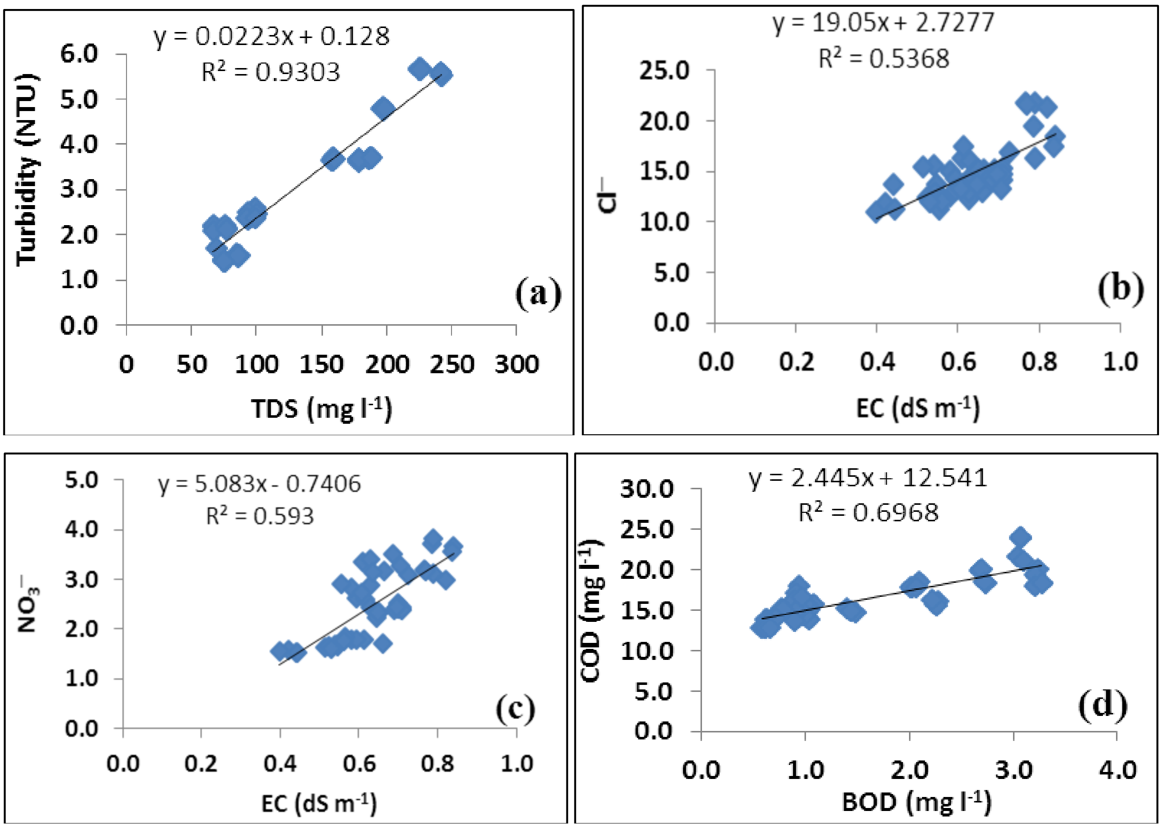

Fig 2: Linear regression analysis of different water parameters **a)** Turbidity vs TDS, **b)** Cl^- vs EC, **c)** NO_3^- vs EC and **d)** COD vs BOD.

Surface water sources recorded very high values of turbidity within 0-500 m distance as compared to those recorded by ground water at >500 m might be due to the presence of suspended matter such as clay, finely divided organic and inorganic matter, silt and other microscopic organisms which were deposited unto the road surfaces during construction activities. These components were washed from the road surfaces into runoffs and this is evidenced by the positive significant correlation coefficient (R^2 = 0.930) observed between Turbidity and TDS respectively. Similarly, EC and Cl^- were positively and significantly correlated (R^2 = 0.536) with each other. High concentration of NO_3^- may due to high EC of ions and positive significant correlation (R^2 = 0.593) between them. Moreover, similar trend of significant positive correlation (R^2 = 0.696) was observed in case of COD and BOD (Figure 2).

Conclusion

The study inferred that road expansion activities and vehicles may be responsible for introducing pollutants in the nearby water sources and leading to deterioration of the water quality. Since, out of all water quality properties only COD was above permissible limits of standard water quality, which is one of the factors for deteriorating water quality. Further regular monitoring and surveillance for quality assessment of water sources, in the wake of detrimental activities caused by highway expansion projects, is needed.

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References

1. Abewickrema AW, Amanthika RW, Abeysinghe AL, Tennakoon RK, Tennakoon AH, Caldera HM, *et al*. Assessment of water quality impacts of highway and road construction projects. In: Proceedings of South Asian Institute of Technology and Medicine Research Symposium on Engineering Advancements, (SAITM), Sri Lanka, 2013, 136-143.
2. Al-Badaii F, Shuhaimi-Othman M, Gasim MB. Water quality assessment of the Semenyih River, Selangor, Malaysia. Journal of Chemistry. Article ID 871056. 2013, 10.
3. APHA. Standard methods for the examination of waste water. (20th edition). Washington DC, 2005, 161.
4. Arismendi I, Groom JD, Reiter M, Johnson SL, Dent L, Meleason M, *et al*. Suspended sediment and turbidity after road construction/improvement and forest harvest in streams of the Trask River Watershed Study, Oregon. Water Resources Research. 2017; 53:6763-6783.
5. Armah FA, Yawson DO, Pappoe AA. A systems dynamics approach to explore traffic congestion and air pollution link in the city of Accra, Ghana. Sustain. 2010; 2:252-265.
6. Barbosa AE, Fernandes JN, David LM. Key issues for sustainable urban strom water management. Water Research. 2012; 46:6787-6798.
7. Chauhan A, Verma SC. Impact of land uses and seasons on physico-chemical characteristics of surface water in Solan district of Himachal Pradesh. Nature Environment and Pollution Technology. 2016; 15(2):667-672.
8. Chen Y, Viadero RC, Wei X, Fortney R, Hedrick LB, Welsh SA, Anderson JT, Lin LS. Effects of Highway Construction on stream water quality and

macroinvertebrate condition in a Mid-Atlantic Watershed, USA. Journal of Environmental Quality. 2009; 38:1672-1682.
9. Chow MF, Yusop Z, Shirazi SM. Storm runoff quality and pollutant loading from commercial, residential and industrial catchments in the tropic. Environmental Monitoring and Assessment. 2013; 185:8321-8331.
10. Dillon KS, Chanton JP. Nutrient Transformations between Rainfall and Stormwater Runoff in an Urbanized Coastal Environment: Sarasota Bay, Florida. Limnology and Oceanography. 2005; 50:62-69.
11. Doamekpor LK, Darko R, Klake RK, Samlafo VB, Bobobee LH, *et al*. Assessment of the contribution of road runoff to surface water pollution in the New Juaben Municipality, Ghana. Journal of Geoscience and Environment Protection. 2016; 4:173-190.
12. Forman RTT, Alexander LE. Roads and their major ecological effects. Annual Review of Ecology and Systematics. 1998; 29:207-231.
13. Fronczyk J, Radziemska M, Dynowski P, Mazur Z, Bazydlo M. Quality of water in the road drainage systems in the Warsaw agglomeration, Poland. Water. 2016; 8(429):1-12.
14. Gasim MB, Ismail BS, Wan NA, Muhammad IY, Marlia MH. Water qulity assessment of the Semenyih river basin Langor, Malaysia. Jurnal Biosains. 2005; 16(10):95.
15. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley and Sons, II (ed) New York, USA, 1984, 680.
16. Harun S, Abdullah MH, Mohamed M, Fikri AH and Jimmy EO. Water quality study for four streams within Maliau basin conservation area, Sabah, Malaysia. Journal of Tropical Biology and Conservation. 2010; 6:109-113.
17. Hewitt CN, Rashed MB. Removal rates of selected pollutants in the runoff waters from a major rural highway. Water Research. 1992; 26(3):311-319.
18. Ibraheem AM, Khan SM, Ravikumar A. Seasonal variation of groundwater quality in Veppanthattai block of Perambalur district, Tamilnadu-implements of the water quality index method. Journal of Chemical and Pharmaceutical Research. 2015; 7(5):938-943.
19. Kayhanian M, Fruchtman BD, Gulliver JS, Montanaro C, Ranieri E, Wuertz S. Review of highway runoff characteristics: comparative analysis and universal implications. Water Research. 2012; 46:6609-6624.
20. Klimaszewska K, Polkowska Z, Namiesnik J. Influence of mobile sources on pollution of runoff waters from roads with high traffic intensity. Polish Journal of Environmental Studies. 2007; 16 (6):889-897.
21. Makineci E, Demir M, Kartaloglu M. Acidity (pH) and electrical conductivity changes in runoff water from ditches of paved and unpaved forest roads. Baltic Forestry. 2015; 21(1):170-175.
22. Ololade IA, Ajayi AO. Contamination profile of major rivers along the highways in Ondo State, Nigeria. Journal of Toxicology and Environmental Health Sciences. 2009; 1(3):38-53.
23. Polkowska Z, Skarzynska K, Dubiella-Jackowska A, Staszek W, Namiesnik J. Evaluation of pollutant loading in the runoff waters from a major urban highway (Gdansk Beltway, Poland). Global Nest Journal. 2007; 9(3): 269-275.
24. Rana A, Bhardwaj SK, Thakur M. Surface water quality and associated aquatic insect fauna under different land-uses in Solan (district Solan), Himachal Pradesh. Indian Journal of Ecology. 2016; 43(1):58-64.
25. Rosli N, Gandaseca S, Ismail J, Jailan MI. Comparative study of water quality at different peat swamp forest of Batang Igan, Sibu Sarawak. American Journal of Environmental Sciences. 2010; 6(5):416-421.
26. Shen Z, Liu J, Aini G, Gong Y. A comparative study of the grain-size distribution of surface dust and storm water runoff quality on typical urban roads and roofs in Beijing, China. Environmental Science and Pollution Research. 2016; 23:2693-2704.
27. Shridharan M, Nathan DS. Groundwater quality assessment for domestic and agriculture purposes in Puducherry region. Applied Water Science. 2017; 7:4037-4053.
28. Singh TA, Meetei NS, Meitei LB. Seasonal variation of some physico-chemical characteristics of three major rivers in Imphal, Manipur: A comparative evaluation. Current World Environment. 2013; 8(1):93-102.
29. Sirohi S, Sirohi SP, Tyagi PK. Impact of industrial effluents on water quality of Kali river in different locations of Meerat, India. Journal of Engineering and Technology Research. 2014; 6(4):43-47.
30. Vieira R, Fernandes JN, Barbosa AE. Evaluation of the impacts of road runoff in a Mediterranean reservoir in Portugal. Environmental Monitoring and Assessment. 2013; 185:7659-7673.
31. Wang YJ, Chen CF, Lin JY. The measurement of dry deposition and surface runoff to quantity urban road pollution in Taipei, Taiwan. International Journal of Environmental Research and Public Health. 2013; 10: 5130-5145.
32. Yannopoulos S, Socrates B, Giannopoulou I. Water body's pollution due to highways stormwater runoff: Measures and legislative framework. Global Nest Journal. 2013; 15(1):85-92.
33. Yew CP, Makowski PB. Water quality monitoring of highway construction, Proceedings of the 1989 National Conference on Hydraulic Engineering, ASCE, New York. 1989, 157-162.