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Impact Assessment of Heavy Metals Accumulation in Surface Water Bodies in the Adjoining Forest of Shoghi-Shimla-Dhali Bypass of Himachal Pradesh

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Abstract: A study was conducted to investigate the impact of seasonal variation in heavy metals concentration of surface water (streams) sampled by collecting 72 samples during pre-monsoon, monsoon and post-monsoon from four study sites. The heavy metals like Cu, Cd, Cr, Pb, and Ni and As, Hg were estimated using inductively coupled plasma emission spectrometer (ICAP-6300 Duo). The concentrations of all heavy metals were within permissible limit except Hg which was not detected as given by BIS and CPCB. The mean value for heavy metals were Cd (0.011,0.013,0.006 mg/l), Cr (0.037,0.039,0.024 mg/l), Pb (0.022,0.024,0.012 mg/l), Cu (0.035,0.043,0.0024 mg/l), Ni (0.022,0.026,0.017 mg/l) and (0.037, 0.041, 0.028 mg/l) recorded during pre-monsoon, monsoon and post-monsoon. Seasonal variations have significant effect on heavy metal concentration of surface water samples. Road construction material like dirt and debris added heavy metals into adjacent water bodies ultimately degraded the water quality in terms of physico-chemical and biological characteristics.

Keywords: Heavy metal, Road construction, National highways, Seasonal variation

Water is an essential resource for the survival of living organism. The change in composition of water which is available at optimum level for suitable growth of biotic components is referred as seasonal variation in quality of water (Raji et al 2016). The metallic elements with density greater than 5g/m^3 and high atomic weight are termed as heavy metals. These metallic elements generally occur in traces as these are toxic in nature and tend to accumulate hence are commonly called as trace metals. Their presence in surface water at above permissible limit is undesirable. Heavy metals affected biological system even at very low concentration. The particulate and sediment has been adsorbed by heavy metals and not available to biological organisms (Qian et al 2015). Heavy metal contamination in the sediment is a significant problem because of their toxicity, non-degradability and easy bioaccumulation potential in biota and food chain (Sundaray 2014). The heavy metals are inert in the sediment environment and often considered as conservative pollutant and can be released into the water in respect to certain disturbances and pose potential risk (Kumar and Maiti 2015, Zhang et al 2015). The various chemical parameters in natural aquatic system occurred in low concentration and this concentration increases as a result of rapid development and exploitation of natural resources. Road construction activities were considered as a major source of pollutants to aquatic bodies as these pollutants generally originated from soil erosion, diesel oil, construction debris and dirt and added to adjacent water bodies directly or indirectly, leading to physical, chemical and biological degradation of water quality (Abewickrema et al 2013). Water quality has been degraded due to pollutants which are produced during road construction as highway runoff accumulate tremendous amount of suspended solids, metals and hydrocarbons such as oil and polycyclic aromatic hydrocarbons (Mooselu et al 2021). A various organic and inorganic pollutants has been obtained from bitumen which is generally obtained from petroleum, vehicle exhaust, lubricating oil and gasoline leached out in nearby water bodies and affect their habitat (Banerjee et al 2018). Surface water bodies have also been affected by crushed ash. Runoff water more contaminated by pollutants which are emitted by vehicles. The leaching of pollutants in water bodies generally depend upon the pH of environment (Licbinsky et al 2012). The present study characterized the effect of road expansion on the quality of surface water, through the use of techniques such as collection of water sample at different sites along the highway and chemical analysis of heavy metals.

MATERIAL AND METHODS

Study area: A 51 m wide and 27 km long stretch of NH-22 (Shoghi- Shimla- Dhali) bypass come across the Mashobra division of district Shimla, located in the land of snowy mountains, Himachal Pradesh and is extended from latitude 31° 05' 10" - 32° 10' 50" in North to longitude 76° 57' 05" - 70° 07' 45" in East in the Western Himalaya (Table 1). The study area was divided into four sites (Fig. 1). The four sites S_1 (Shunghal), S_2 (Raghanv), S_3 (Majjhar) and S_4 (Dhali) were selected in order to study the effect of highway expansion activity on heavy metal concentration in surface water.

Sample collection: In the year 2018 and 2019, the surface water (streams) samples were collected during pre-monsoon (April and May), monsoon (June, to September) and the post-monsoon (October and November) seasons from each site based upon weather report and laboratory workload. In total there were 12 treatment combinations (4×3) which were replicated three times in randomized block design.

Sample preparation: Samples were collected in 2 litters' plastic bottles. Collection was carried out by careful immersion of sample bottles deep inside the water and sealing with tight fitting corks after collection in order to avoid air bubbles and labelled with the appropriate sample site no. Samples were transferred the refrigerator at 4°C prior to analysis.

Sampling method and analysis: For heavy metal (Cd, Cr, Pb, Cu, As, Ni and Hg) analysis, the samples were preserved at temperature below 4°C but slightly above the freezing point, by adding one ml concentrated nitric acid to avoid microbial utilization. The samples were analysed as per the procedures by APHA (2012). The water samples were first filtered using whatman filter paper (No. 1). The heavy metals were estimated using Inductively Coupled Plasma Emission Spectrometer (ICAP-6300 Duo) and expressed as mg/l.

Interpretation of water quality: The water quality parameters of surface water (streams) studied at different sites of the study area was compared with water standards prescribed by Bureau to Indian Standard (BIS, 2015) and Central Pollution Control Board (CPCB) and was used to discuss the results on effects of highway expansion on water quality.

Statistical analysis: The data recorded were statistically analysed by using OPSTAT.

RESULTS AND DISCUSSION

Spatial and Seasonal Variation in Heavy Metals concentration in Surface Water

Cadmium : The cadmium in surface water bodies lies in between 0.004 to 0.015 mg/l which was within the permissible limits as mentioned by BIS (Table 2). The pooled effect showed a significant seasonal variation with respect to chromium. The average maximum cadmium (0.013 mg/l) concentration was in monsoon, followed by pre monsoon (0.011 mg/l) while the lowest (0.006 mg/l) in post-monsoon season. It might be due to the movement of waste leachates with the runoff enhanced the concentration of cadmium in monsoon. Dan et al (2014) also reported higher cadmium concentration in water in monsoon season. Wearing of old tyres and leakage of lubrication oil was considered as the major source of cadmium (Doamekpor et al 2016).

Chromium : The chromium concentration lies in between the range from 0.022 to 0.041 mg/l in water sources located along the national highway which was within permissible limits of 0.05 mg/l as mentioned by BIS (Table 3). The pooled effect of both the years on distribution of chromium in water bodies followed a decreasing pattern from monsoon > pre-monsoon> post monsoon (0.039, 0.037 and 0.024 mg/l). The chromium concentration enhanced in the surface water bodies in monsoon might be due to weathering of soil and rocks found in earth crust (Akpe et al 2018). The major source of cadmium was brakes and tyres wear (Xue et al 2020). The

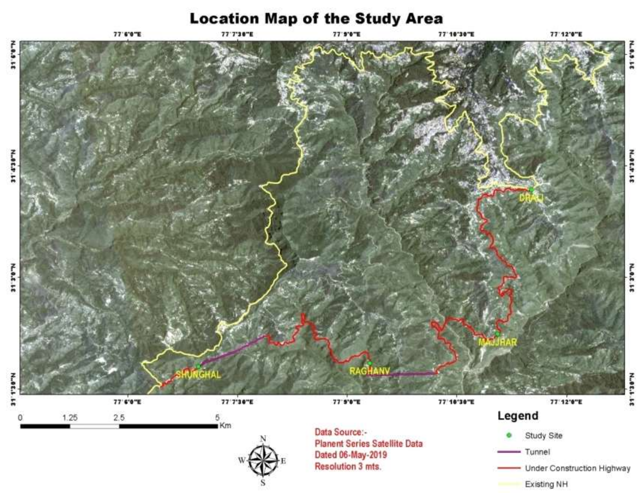

Fig. 1. Location map of the study area

Table 1. Global positioning system of study area

Parameters	Characteristics
Elevation	1493 – 2250 m
Slope range	100 - 300 m (Solan); 300 - 400 m (Shimla)
Soil	Sandy loamy (Solan); Alluvial (Shimla)
Minerals	Sand, Stone in (Solan); Lead, Zinc Dolomites (Shimla)
Temperature	14 -28C (Summer); 1.7 to 14.8C (Winter)
Rainfall	1450 mm in Solan;1253 mm in Shimla
Relative humidity	33 to 91 %
Land use pattern	Open, Barren, Cultural Waste Land
Wind speed	1.7 to 3.8 km/h
Vegetation	Tropical dry deciduous forest and Himalayan Chir pine forests
Global positioning system	31° 05' 10" - 32° 10' 50" N 76° 57' 05" - 70° 07' 45"E

results are in collaboration with the findings of Polkowska et al (2007) where higher concentration of heavy metals was in monsoon seasons.

Lead: The lead concentration range from 0.012 to 0.026 mg/l in water sources along the national highway which was within permissible limits as mentioned by BIS (Table 4). The average highest (0.024 mg/l) of lead content was in monsoon while the lowest (0.012 mg/l) concentration of lead was in post- monsoon. The influence of three way interaction year x season x site was significant. The highest (0.028 mg/ l) lead content was d at Dhali in the monsoon during 2019 while the lowest (0.008 mg/l) concentration of lead was at Raghanv in the post- monsoon during 2018.Generally it is present in low concentration in natural bodies due to its less solubility in water, ultimately it become toxic and difficult to eliminate and affect aquatic environment because of bottom feeding habit of aquatic organisms (Muhammad et al 2014). The increase in monsoon due to dry and wet deposition (Zhang et al 2007) of atmospheric fallouts from traffic emissions and from vehicular exhaust (Valavanidis and Vlachogianni 2010). It aligns with earlier work where traces of heavy metals were detected in water bodies in monsoon (Raji et al 2016). Combustion of leaded gasoline was considered as the major source since it was the most distinctive heavy metal from road traffic pollution (Xue et al 2020).

Copper: The concentration of copper in surface water bodies ranged from 0.023 to 0.046 mg/l which was within the permissible limits (Table 5). The maximum (0.043 mg/l) value of copper content was in monsoon while the lowest (0.024 mg/l) in post-monsoon. Higher concentration in monsoons might be due to weathering of rocks and soil. Akpe et al (2018) also observed higher copper concentration in water in monsoon season. The variation in copper concentration at different water sources in study area showed the maximum copper in surface water bodies at Dhali (0.036 mg/l) while lowest was at Majjhar and Raghanv (0.032 mg/l). The highest

Table 2. Spatial and seasonal variations in cadmium concentration (Cd-mg/l) of surface water at different sites

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.013	0.011	0.004	0.009	0.009	0.012	0.004	0.009	0.011	0.012	0.004	0.009
Raghanv	0.009	0.012	0.006	0.009	0.013	0.013	0.006	0.011	0.011	0.013	0.006	0.010
Majjhar	0.012	0.014	0.008	0.011	0.013	0.012	0.005	0.010	0.012	0.013	0.007	0.011
Dhali	0.009	0.016	0.007	0.011	0.008	0.014	0.007	0.010	0.009	0.015	0.007	0.010
Mean	0.011	0.013	0.006	0.010	0.011	0.013	0.005	0.010	0.011	0.013	0.006	0.010
CD (p=0.05)		Sites		NS		Sites		NS		Sites		NS
		Season		0.002		Season		0.002		Season		0.001
		Site x season		NS		Site x season		NS		Site x season		0.003
		-		-		-		-		Site x season x year		NS

Desirable Limit (mg/l) : 0.01

Table 3. Spatial and Seasonal variations in Chromium concentration (Cr-mg/l) of surface water at different site

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.039	0.041	0.024	0.034	0.036	0.038	0.020	0.031	0.037	0.040	0.022	0.033
Raghanv	0.04	0.039	0.027	0.035	0.032	0.037	0.024	0.031	0.036	0.038	0.025	0.033
Majjhar	0.036	0.042	0.029	0.036	0.033	0.039	0.023	0.032	0.035	0.041	0.026	0.034
Dhali	0.039	0.041	0.020	0.034	0.039	0.037	0.025	0.034	0.039	0.039	0.023	0.034
Mean	0.039	0.041	0.025	0.035	0.035	0.038	0.023	0.032	0.037	0.039	0.024	0.033
CD (p=0.05)		Sites		NS		Sites		NS		Sites		NS
		Season		0.002		Season		0.002		Season		0.001
		Site x season		NS		Site x season		NS		Site x season		NS
		-		-		-		-		Site x season x year		NS

Desirable Limit (mg/l) : 0.05

copper was at Dhali (0.046 mg/l) in monsoon while the lowest (0.023 mg/l) was at Shunghal and Majjhar in the post-monsoon season. The combined effect of seasons x sites x year was significant and maximum was in monsoon at Dhali (0.049 mg/l) during 2019 while the lowest (0.021 mg/ l) copper was noticed in post-monsoon season at Shunghal in 2019 and at Majjhar in 2018. The possible source of copper in surface water might be metal plating, wear of bearing and brake parts (Budai and Clement 2011).

Nickel: The nickel concentration in surface water bodies in the study area varied from 0.014 to 0.028 mg/l (Table 6) which was within the permissible limit of nickel in water is as prescribed by BIS. The pooled effect of both the years indicated that average highest nickel (0.026 mg/l) was in monsoon while lowest (0.017 mg/l) concentration of nickel in post-monsoon. It might be due to strong scouring effect which is called first flush effect (Ghosh and Maiti 2018) in monsoon whereas in pre-monsoon small particles were washed away by the light rainfall. Among different sites highest concentration of nickel (0.023 mg/l) was in Dhali while lowest in Majjhar and Raghanv(0.020 mg/l). The interaction among season and sites was significant and indicated highest concentration in monsoon at Shughal (0.028 mg/l) while the lowest) concentration was in post-monsoon season at Raghanv(0.014 mg/l. The combined effect of year x season x site was found to be significant and revealed that the highest (0.030 mg/l) nickel was at Dhali and Shunghal in the monsoon of the year 2019. However, lowest (0.011 mg/l) concentration was at Raghanv in 2019 and in 2018 at Majjhar during post-monsoon season. The presence of higher nickel concentration may be due to natural as well as anthropogenic causes. Nickel comes from mainly gasoline, lubricating oil, bearing wear and break part wear (Xue et al 2020).

Arsenic: The concentration of arsenic in surface water bodies ranged from 0.026 to 0.041mg/l which was within the

Table 4. Spatial and seasonal variations in lead concentration (Pb-mg/l) of surface water at different site

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.020	0.024	0.011	0.018	0.024	0.025	0.012	0.021	0.021	0.024	0.012	0.019
Raghanv	0.021	0.023	0.008	0.017	0.022	0.026	0.016	0.021	0.022	0.025	0.012	0.019
Majjhar	0.023	0.021	0.011	0.018	0.025	0.026	0.014	0.022	0.024	0.023	0.013	0.020
Dhali	0.019	0.024	0.013	0.019	0.025	0.028	0.012	0.022	0.022	0.026	0.013	0.020
Mean	0.021	0.023	0.011	0.018	0.024	0.026	0.014	0.022	0.022	0.024	0.012	0.020
CD (p=0.05)		Sites		NS		Sites		NS		Sites		NS
		Season		0.002		Season		0.002		Season		0.001
		Site x season		0.003		Site x season		NS		Site x season		NS
		-		-		-		-		Site x season x year		0.004

Desirable Limit (mg/l) : 0.05

Table 5. Spatial and seasonal variations in copper concentration (Cu-mg/l) of surface water at different site

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.038	0.034	0.026	0.033	0.039	0.044	0.021	0.034	0.039	0.039	0.023	0.034
Raghanv	0.033	0.041	0.023	0.033	0.033	0.046	0.029	0.036	0.033	0.044	0.026	0.032
Majjhar	0.029	0.047	0.021	0.032	0.031	0.038	0.024	0.031	0.030	0.042	0.023	0.032
Dhali	0.031	0.042	0.025	0.033	0.041	0.049	0.026	0.038	0.036	0.046	0.025	0.036
Mean	0.033	0.041	0.024	0.033	0.036	0.044	0.025	0.035	0.035	0.043	0.024	0.034
CD (p=0.05)		Sites		NS		Sites		0.003		Sites		0.002
		Season		0.002		Season		0.002		Season		0.002
		Site x season		0.004		Site x season		0.005		Site x season		0.003
		-		-		-		-		Site x season x year		0.004

Desirable Limit (mg/l) : 0.01

permissible limits as prescribed by BIS (Table 7). The data with respect to pooled effect of both the years indicated that seasonally average highest concentration of arsenic (0.041 mg/l) was in monsoon which was statistically at par with (0.037 mg/l) in pre-monsoon while the lowest (0.028 mg/l) arsenic was in post-monsoon season. Higher concentration in monsoons may probably be due to transportation of waste leachates with the runoff of rainwater as also reported by Li and Zhang (2010.) The major source of arsenic in surface water comprises road runoff due to tyre wear and corrosion of radiators (Dixit and Tiwari 2008).

The monsoon season showed the highest concentration for all the heavy metals as compared to other two seasons. In pre-monsoon season, rainwater had less scouring power on particles and the contact time between rain water and pavement sediments was longer before runoff formation. It means that soluble pollutants could dissolve into runoff water in the early stage and non -soluble pollutants were brought into runoff under scouring effect of rain water having high intensity (Wang et al 2017). Concentration of heavy metals in water samples was greater in pre-monsoon than post-monsoon due to lessor inflow of water which decrease the water column to dilute heavy metals during pre-monsoon period (Karunanidhi et al 2022). Spatial variation in heavy metals concentration among all sites might be due to combination of certain factors like rainfall precipitation intensity, duration, vehicular emission and antecedent sunny days (Xue et al 2020). In pooled data, the interaction among sites x season showed non-significant effect for heavy metal Cr, Pb, As whereas Cd, Cu, Ni showed significant effect. The interaction among sites x season x year showed non-significant effect for Cd, Cr, Pb, Cu and Ni showed significant variation. The positive skewness value point towards heavy metals distribution with along right tail was shown by Pb and

Table 6. Spatial and seasonal variations in nickel concentration (Ni-mg/l) of surface water at different site

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.018	0.026	0.013	0.019	0.022	0.030	0.020	0.024	0.020	0.028	0.016	0.021
Raghanv	0.021	0.023	0.018	0.021	0.019	0.029	0.011	0.020	0.020	0.026	0.014	0.020
Majjhar	0.019	0.025	0.011	0.018	0.026	0.022	0.019	0.022	0.023	0.024	0.015	0.020
Dhali	0.021	0.021	0.016	0.020	0.026	0.030	0.025	0.027	0.024	0.026	0.021	0.023
Mean	0.020	0.024	0.014	0.020	0.023	0.028	0.019	0.023	0.022	0.026	0.017	0.021
CD (p=0.05)		Sites		NS		Sites		0.003		Sites		0.002
		Season		0.002		Season		0.002		Season		0.002
		Site x season		0.004		Site x season		0.005		Site x season		0.003
		-		-		-		-		Site x season x year		0.004

Desirable Limit (mg/l) : 0.02

Table 7. Spatial and seasonal variations in arsenic concentration (mg/l) of surface water at different sites

Season/ Site	2018				2019				Pooled			
	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean	Pre-monsoon	Monsoon	Post-monsoon	Mean
Shunghal	0.037	0.039	0.029	0.035	0.038	0.044	0.031	0.038	0.038	0.041	0.030	0.036
Raghanv	0.035	0.041	0.024	0.033	0.040	0.041	0.035	0.039	0.038	0.041	0.029	0.036
Majjhar	0.034	0.037	0.021	0.031	0.039	0.042	0.033	0.038	0.036	0.040	0.027	0.034
Dhali	0.036	0.042	0.025	0.034	0.038	0.045	0.028	0.037	0.037	0.040	0.026	0.036
Mean	0.035	0.040	0.025	0.033	0.039	0.043	0.032	0.038	0.037	0.041	0.028	0.036
CD (p=0.05)		Sites		0.003		Sites		NS		Sites		NS
		Season		0.003		Season		0.002		Season		0.002
		Site x season		NS		Site x season		NS		Site x season		NS
		-		-		-		-		Site x season x year		NS

Desirable Limit (mg/l) : 0.02

Table 8. Distribution of heavy metals in study area

Heavy metals	Skewness						Kurtosis					
Site	Cd	Cr	Pb	Cu	Ni	As	Cd	Cr	Pb	Cu	Ni	As
Shunghal	-0.534568	-0.911979	-0.700254	-0.53307	0.0627613	-0.128919	-1.98253	-1.35803	-1.98026	-1.00664	-0.27258	-0.73721
Raghanv	-0.326751	-0.44806	-1.262313	0.2359016	-0.099053	-1.538635	-2.43484	-1.84181	1.418022	-0.51749	1.158431	2.411223
Majjhar	-1.074734	-0.518567	-0.749483	0.7510213	-0.993199	-1.382434	-0.08048	-0.42045	-1.36798	-0.05982	1.092576	2.464304
Dhali	0.9303202	-1.01693	-0.273994	0.1804542	-0.10472	-0.367416	-1.25371	-1.06453	-2.00553	-1.89909	-0.13036	-1.43951

As in all sites whereas Cr showed positive value at Shunghal and Majjhar. The Cd and Ni showed distribution with a long right tail at Dhali and Shunghal. Inspite of these, Cd and Ni showed negative value of skewness which gives distribution with a significant long left tail at sites Shunghal, Raghanv and Majjhar and Raghanv, Majjhar and Dhali respectively. The Cr had distribution with significant long left tail at Raghanv and Dhali, whereas at Shunghal Cu showed distribution with a significant long left tail. The negative value of Kurtosis observed for heavy metals (Cd, Cr, Cu) at all sites where as Pb and Ni, As were observed with negative value of kurtosis at sites Shunghal, Majjhar, Dhali and Shunghal and Dhali respectively showed flat distribution around study area. The positive value of Kurtosis for heavy metals (Cu and Pb) at site Raghanv showed non-uniform distribution throughout the study area. Apart from these, Ni and As were observed with positive value at site Raghanv and Majjhar showed non–uniform distribution around the respective study areas (Table 8).

CONCLUSION

The heavy metal concentration lies within the permissible limit and does not affect water quality beyond permissible limit. The concentration of heavy metals in surface water samples vary depending upon sediment, pollutant and exhaust gases during construction of roads. Further, the quality of water needs to be monitored regularly in wake of detrimental impacts caused by national highway expansion activities.

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