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Effect of vehicular pollution on physicochemical parameters and accumulation of heavy metals along roadside soils in Sonamarg forest ecosystem

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Abstract
In an attempt to evaluate the effect of vehicular pollution on physicochemical parameters and accumulation of heavy metals on soil along roadside in Sonamarg forest ecosystem, soil samples from three different locations (Sonamarg, Baltal, Thajwas) comprising of disturbed and undisturbed sites were collected. The results indicated that the soils at all the study sites fall in the sandy loam class. Significant increase was recorded in soil pH and electrical conductivity in disturbed sites during both autumn and spring seasons. Moisture content was found higher at undisturbed sites in both the seasons and spring season recorded higher moisture content than the autumn season at all the locations and sites as well. Results showed that the heavy metals were of the ranges: Pb (0.173-1.283ppm), Zn (1.215-4.045ppm), Ni (0.637-1.753ppm), Cu (0.425-1.124ppm) and Cd (0.037-0.093ppm) respectively. Soil heavy metal concentration significantly decreased with increase in distance from the roadside. Autumn season showed higher depositions of heavy metals along the road than the spring season. Furthermore, the concentration of Zn was observed to be highest followed by Ni, Pb, Cu and Cd with mean values of 4.045, 1.753, 1.283, 1.124 and 0.093 ppm respectively.

Keywords: Heavy metals, Pinus spp., Forest, Roadside

Introduction

Soil is a key part of the Earth system as it controls the hydrological, erosional, biological and geochemical cycles. The soil system also offers goods, services and resources to humankind (Berendse *et al*., 2015; Brevik *et al*., 2015; Decock *et al*., 2015; Smith *et al*., 2015) [4, 6, 7, 30].
Soil is a dynamic, natural body occurring on the surface of the earth which provides a place for plants, animals and microbial life and also a natural reservoir for metals. Its heavy metal concentration is associated with biogeochemical cycle, parent material, mineralogy, soil age, organic matter, particle size distribution, soil pH, redox concentration, oxidation state and microbial activities (Ma *et al*., 1997; Lee *et al*., 2002; Ebong *et al*., 2007; Ololade *et al*., 2007) [19, 17, 9, 21]. Soils have been used to detect the deposition, accumulation and distribution of heavy metals (Onder *et al*., 2007) [22].
Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded (Mmolawa *et al.*, 2011) [20].
Road construction has been the main activity for development of industrial units. This has led to the loss of forest cover and subsequent loss of soil fertility.
Soils often show a high degree of contamination that can be attributed to motor vehicles. Various researchers have found that the concentrations of the metals lead, copper, zinc, cadmium and nickel decrease rapidly within 10 to 50 m from the roadsides (Pagotto *et al*., 2001; Joshi *et al*., 2010) [23, 15].
According to Panek and Zawodny (1993) [25] pollution of roadside soils and plants by combustion of leaded petrol products is localized and usually limited to a belt of several metres wide on either side of the road. The high concentration of heavy metals along the roadside soils is due to high influx of motor vehicles (Pavlovic *et al*., 2016) [26] which is considered as one of the major sources of heavy metal contamination (Devi *et al*., 2015; Jia *et al*., 2018) [8, 14].

Over the last few years, the levels of heavy metals in the forest soil are increasing as a result of increasing environmental pollution from industrial, agricultural and vehicular emissions. Emissions of smoke from heavy traffic were reported to contain lead, cadmium, zinc and nickel which are present in fuel as anti-knock agents (Atayese *et al*., 2009) [2]. Vehicle exhausts emit these heavy metals such that soils, plants and even residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals (Ghrefat and Yusuf, 2006) [12].

In order to assess the accumulation and subsequent deterioration of soil health by heavy metals released from vehicular pollution, current investigation in roadside soils of Sonamarg forest was carried out.

Material and methods

Study area

The Jammu and Kashmir is the northern state of India situated between 32.15˚- 37.05˚N and 72.35˚- 83.20˚E with its summer capital Srinagar situated at an elevation of 5200 feet above sea level. The study was carried out in Sonamarg, which is located at 34.18°N and 75.15°E having an average elevation of 8989 feet lies about 79.4-km from Srinagar (fig.1). It is very famous health resort in the state of Jammu and Kashmir. The route to Sonamarg passes through the dense forest having the dominant pine species of *Pinus wallichaina* (Jackson), *Abies pindrow* (Royle) and *Cedrus deodara* (Roxb.ex D. Don).

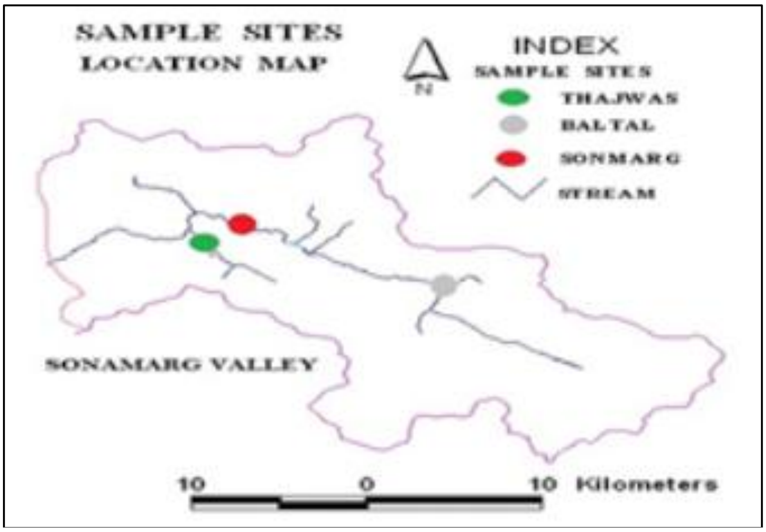

Fig 1: Map of study area showing position of sampling sites

Soil Sampling

Soil samples were taken from three different sampling sites *viz*., Baltal, Sonamarg and Thajwas with each location comprising of disturbed (up to 10 m from road) and undisturbed (about 150 m away from road) sites. Sampling was carried out in two different seasons, first in autumn (September, 2017) and second in spring (April, 2018). Soil samples were taken from soil layer (0-30 cm) within the rhizosphere of *Pinus* spp. at all the three sites after removing the leaf litter, debris etc.

The samples were transferred int polythene bags, labeled and taken to the laboratory for analysis. Samples for determining the moisture content were taken separately in sealed moisture boxes.

Analysis of soil samples

Soil samples collected were dried in shade and all clods and clumps were removed. Dried soil was sieved using 2 mm sieve to remove coarse particles before analysis. The following parameters were analyzed in the soil samples soil texture, soil pH, soil electrical conductivity, soil moisture and heavy metals (Pb, Zn, Ni, Cu and Cd).

Texture of the soil was determined by hydrometric method (Bouyoucos, 1962) [5]. Soil pH and electrical conductivity was determined by potentiometric method with the help of pH meter and electrical conductivity meter (Jackson, 1973) [13]. Soil moisture was determined by gravimetric method (Prihar and Sandhu, 1968) [28]. In this method fresh soil samples were taken and sealed at the site of collection in moisture boxes. The soil was weighed in moisture boxes of known weight and then kept in oven at 105^{o}C. After two days, samples with zero per cent of moisture were weighed again. Moisture percentage was then determined by the following formula:

$$\text{Moisture percentage (per cent)} = \frac{\text{Loss of weight}}{\text{Oven dry weight}} \times 100$$

The presence of heavy metals was determined by Lindsay and Norwell's method (1978) [18] using DTPA extraction method with the help of atomic absorbtion spectrophotometer (AAS). In this method 10 g of sieved soil sample and 20 ml DTPA solution were taken in flasks and was shaken for two hours. After shaking the contents were filtered through Whatman's filter paper No. 42 and crystal clear filtrates were collected in glass tubes and these were analyzed for detection of heavy metals *viz*., Pb, Cu, Ni, Cd and Zn.

Statistical analysis

Statistical analysis was carried out by using Microsoft excel 2010 and online Opstat software.

Results and discussion

Physicochemical properties

The results on various physicochemical characteristics for the present study depicted diverse trends which are mentioned as: from the Table 1, The average clay, silt and sand contents of undisturbed sites were found in the order of 13.43, 34.23 and 52.33 per cent respectively. Similarly the average clay, silt and sand contents at the disturbed sites were found 11.43, 35.06 and 53.50 per cent, respectively. Using the USDA graph for the determination of soil textural classes, The soil under study area fall in the sandy loam class.

Table 1: Particle size distribution of the soils of the experimental site

Site	Clay (per cent)	Silt (per cent)	Sand (per cent)	Type
Baltal disturbed	12.2	39.1	48.7	Sandy loam
Baltal undisturbed	13.7	35.9	50.4	
Sonamarg disturbed	10.7	33.6	55.7	
Sonamarg undisturbed	13.3	34.6	52.1	
Thajwas disturbed	11.4	32.5	56.1	
Thajwas undisturbed	13.3	32.2	54.5	

As depicted in Table 2, high soil pH (6.96) was found at disturbed site of Sonamarg while the lowest pH was found at undisturbed site of Thajwas with a value of (5.92) in autumn season. During spring season, the highest average soil pH (6.64) was found to be at disturbed site of Sonamarg and the lowest pH (5.33) was found at undisturbed site of Thajwas. Similarly, the highest soil electrical conductivity (0.83 ds m^{-1}) was found at disturbed site of Sonamarg with lower value (0.56 ds m^{-1}) at undisturbed site of Thaj was in autumn season. During spring season the highest soil electrical conductivity (0.52 ds m^{-1}) was found at disturbed site of Sonamarg while the lowest value of electrical conductivity (0.21 ds m^{-1}) was found at undisturbed site of Thaj was. The high moisture content (23.73 per cent) was found at undisturbed site of Thaj was while as disturbed site of Sonamarg showed lower moisture content (13.90 per cent) during autumn season. In spring season higher moisture content (27.09 per cent) was found at undisturbed site of Thaj was with lower value (16.22 per cent) at disturbed site of Sonamarg. The data revealed that the moisture content was significantly higher in undisturbed soils than in the disturbed soils**.**

Heavy metal content in soil

Results showed that heavy metal concentrations in soil decreased with increase in distance from the road.

From the Table 3, The results revealed that autumn season recorded the highest average values of lead (1.283 ppm), zinc (4.045 ppm), copper (1.124 ppm) and cadmium (0.093 ppm) respectively at disturbed site of Sonamarg whereas highest nickel content (1.753 ppm) was found at disturbed area of Thaj was. The lowest average values of lead (0.213 ppm), zinc (1.533 ppm), copper (0.443 ppm), cadmium (0.043 ppm) were found at undisturbed site of Thaj was whereas lowest nickel content (0.743 ppm) was found at undisturbed site of Sonamarg. During spring season, the highest average values of lead (0.885 ppm), zinc (3.893 ppm), copper (1.053 ppm), cadmium (0.084 ppm) were found at disturbed site of Sonamarg with lower values of lead (0.173 ppm), zinc (1.215 ppm), copper (0.45 ppm), cadmium (0.037 ppm) at the undisturbed site of Thaj was Whereas the highest nickel content (1.747 ppm) was found at disturbed site of Thaj was with lower value (0.637 ppm) at undisturbed site of Sonamarg. The concentration of Zn, Ni, Pb was found higher at disturbed sites as compared to the undisturbed sites at all locations in both seasons.

Discussion

Decrease in vegetation cover in forest had left soil naked, thus resulting in sandy loam textural class. Similar findings were reported by Faruqi *et al.* (2013) [10]; Singh *et al.* (2018) [31]. Generally the forest soil is characterized by slightly acidic to neutral pH in nature. Higher pH and electrical conductivity was observed in disturbed sites as compared to undisturbed ones. Significant increase was recorded in soil pH and electrical conductivity in disturbed area during both autumn and spring seasons. Increase in pH in deforested area is attributed to decrease in organic matter accumulation which directly depends upon the forest cover. The increase in pH can also be attributed to decrease in accumulation and subsequent slow decomposition of organic matter, which releases acids (de Hann, 1977). Higher pH and electrical conductivity near to the highway and lower away from highway could be due to decline of forest flora. These results were found in concordance with results of Grigalaviciene *et al*. (2005); Joshi *et al.* (2010) [15]; Das and Dkhar (2011) and Shah and Jeelani (2015); Singh *et al.* (2018) [31]. Higher moisture content was found in spring season as compared to the autumn season which may be attributed to high rate of precipitation in spring than autumn. The roadside disturbed forest soil contained less moisture due to higher evapo-transpiration losses of its exposed land resulted by the loss of forest cover. The results obtained were in concordance with results observed by Joshi *et al*. (2010) [15]; Faruqi *et al.* (2013) [10] and Shah and Jeelani (2015).

Heavy metals in soil

The soil environment is an important sink for heavy metals. The content of heavy metals (Pb, Cu, Zn, Ni and Cd) was observed higher in disturbed area as compared to the undisturbed area at all the sites in both the seasons. It was observed from (Table 3) that autumn season showed higher accumulation of heavy metals than spring.

The increased content of heavy metals accumulation may be due to increase in traffic movements, which results in high rate of exhausts, wear and tear of motor vehicle tyres and other vehicle services could have added high degree of heavy metal contaminations to the roadside soil (Paggotto *et al*., 2001). Weckwerth (2001) [33]; Ramakrishnaiah and Somashekar 2003) [29] reported that roadside soil contains high percentage of heavy metal contamination. Kord *et al.* (2010) [16] also reported that the highest and the lowest metal content were found in the heavy traffic zone and low traffic zone respectively. Wang *et al.* (1996) [32] also revealed that all roadside soils contained higher lead levels than soil near to little motor traffic or no traffic sides. Remarkable high levels of heavy metals were found in the nearest point to high-way (Garcia and Millan, 1994) [11]. Heavy metals (Pb, Zn, Cu and Cd) showed an increasing trend in their content with increased urbanization and transportation (Aksoy and Ozturk, 1996) [3].

These results were in agreement with findings of Aksoy and Ozturk (1996) [3]; Paggotto *et al*. (2001); Wreckwerth (2001); Petrova *et al.* (2014) [27]; Panda and Dhal (2015) [24]; Singh *et al.* (2018) [31].

During the study, the positive correlation was observed between pH and the concentration of heavy metals in the soils (table 4). A similar finding was reported by Agnieszka *et al.* (2014) [1].

Table 2: Effect of vehicular pollution on physicochemical properties in pine forest soil along Sonamarg Highway in autumn and spring seasons.

	Location	Site	pH	EC (ds/m)	Moisture content (%)
Autumn season	Sonamarg	Disturbed	6.968±0.033	0.830±0.031	13.90±0.031
		Undisturbed	6.688±0.034	0.731±0.031	19.14±0.031
	Baltal	Disturbed	6.756±0.049	0.741±0.031	15.77±0.031
		Undisturbed	6.384±0.033	0.630±0.031	20.50±0.031
	Thajwas	Disturbed	6.530±0.031	0.681±0.031	18.30±0.039
		Undisturbed	5.928±0.028	0.560±0.031	23.73±0.044
Spring season	Sonamarg	Disturbed	6.640±0.038	0.520±0.031	16.22±0.031
		Undisturbed	5.664±0.030	0.410±0.031	21.44±0.032
	Baltal	Disturbed	6.414±0.036	0.391±0.031	20.72±0.028
		Undisturbed	5.736±0.036	0.281±0.031	23.93±0.034
	Thajwas	Disturbed	6.340±0.041	0.320±0.031	24.53±0.039
		Undisturbed	5.338±0.034	0.211±0.031	27.09±0.036

Table 3: Effect of vehicular pollution on heavy metal content (ppm) in pine forest soil along Sonamarg Highway in autumn and spring seasons.

	location	Site	Pd	Cu	Ni	Cd	Zn
Autumn season	Sonamarg	Disturbed	1.283±0.003	1.124±0.003	1.042±0.0036	0.093±0.003	4.045±0.003
		Undisturbed	0.511±0.003	0.913±0.003	0.743±0.003	0.079±0.003	2.606±0.002
	Baltal	Disturbed	0.903±0.449	0.843±0.003	1.684±0.003	0.073±0.003	3.924±0.003
		Undisturbed	0.413±0.003	0.634±0.003	0.933±0.003	0.064±0.003	2.316±0.003
	Thajwas	Disturbed	0.814±0.003	0.757±0.004	1.753±0.003	0.058±0.003	2.432±0.003
		Undisturbed	0.213±0.003	0.443±0.003	1.547±0.0034	0.043±0.003	1.533±0.002
Spring season	Sonamarg	Disturbed	0.885±0.004	1.053±0.003	1.016±0.003	0.084±0.003	3.893±0.003
		Undisturbed	0.497±0.003	0.745±0.004	0.637±0.003	0.068±0.003	2.106±0.002
	Baltal	Disturbed	0.791±0.003	0.824±0.003	1.584±0.003	0.065±0.003	3.414±0.003
		Undisturbed	0.384±0.003	0.616±0.002	0.743±0.003	0.051±0.003	1.986±0.003
	Thajwas	Disturbed	0.394±0.003	0.734±0.003	1.747±0.003	0.041±0.003	2.014±0.002
		Undisturbed	0.173±0.003	0.425±0.003	1.487±0.003	0.037±0.003	1.215±0.003

Table 4: Correlation coefficient between soil properties and heavy metals along Sonamarg highway

	pH	EC	SM	Pb	Zn	Ni	Cu
EC	0.393						
SM	-0.817**	-0.508					
Pb	0.782**	0.211	-0.916**				
Zn	0.805**	0.191	-0.905**	0.922**			
Ni	0.166	- 0.360	0.116	0.034	-0.016		
Cu	0.773**	0.211	-0.865**	0.880**	0.887**	-0.227	
Cd	0.672**	0.506	-0.910**	0.817**	0.854**	0.445	0.902**

*$p<0.05$, **$p<0.01$: where, EC, electrical conductivity; SM, soil moisture

Conclusion

Physicochemical properties and levels of heavy metals in roadside soils of some selected locations along roadside were determined in this study. Heavy metal concentrations in roadside soil samples are mostly higher than those in the soil of undisturbed area due to metals emitted from vehicle exhausts which in turn leads to changes in the physicochemical properties of the soil. Higher content of heavy metals along roadside indicates vehicular pollution alarm at Sonamarg tourist resort thus needs to be tackled scientifically. Proper biomonitoring of the environment should be done as often as possible so as to enlighten the public on the dangers of heavy metal pollution.

Conflict of interest: There is no conflict of interest among the authors.

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