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To study the impact of automobile emission on physicochemical and biological properties of soil

Nisha, Manoj Kumar
Department of Botany, Baba Mastnath University, Rohtak, Haryana, India

Abstract
This study investigates the impact of highway proximity on soil physicochemical and biological parameters in wheat (*Triticum aestivum)* and pearl millet (*Pennisetum glaucum*) cultivation. Soil samples were collected at two developmental stages from control sites (200 m away from the highway) and experimental sites (roadside) for both crops. Key parameters analysed included pH, electrical conductivity (EC), organic carbon (OC), macro-nutrients (K, P, N), total microbial count, dehydrogenase activity (DHA), and alkaline phosphatase (ALP) activity.
Results indicated that roadside soils exhibited increased EC and slightly elevated pH levels compared to control sites, suggesting possible accumulation of vehicular pollutants. Organic carbon content and available potassium and phosphorus were generally lower in roadside soils, particularly in wheat fields. Nitrogen levels showed a decreasing trend at roadside sites across both crops. Microbial activity, reflected in total microbial counts, DHA, and ALP activity, was consistently higher in control sites, particularly for wheat, indicating a negative influence of vehicular emissions on soil biological health.
Overall, the findings suggest that highway proximity alters key soil parameters, potentially impacting crop productivity and long-term soil fertility. Monitoring and mitigation strategies are essential to preserve soil health in areas subjected to vehicular pollution.

Keywords: Physicochemical, electrical conductivity, organic carbon, alkaline phosphatase

Introduction
Soil health plays a pivotal role in crop productivity and sustainability, particularly in environments exposed to anthropogenic disturbances such as vehicular pollution. Roadside agricultural fields are especially vulnerable to pollutants emitted by traffic, which may alter soil physicochemical and biological properties, thereby impacting plant growth and yield. Anthropogenic activities drive certain changes in our ecosystems that can hurt and disable the functions of these ecosystems. Soil ecosystem, including soil living organisms, is among the ecosystems that directly suffer from these changes. Soil properties in general changes due to vehicular pollution are soil acidification, increased conductivity, disruption in microbial communities, affecting nutrient cycling and organic matter decomposition, shortage of nutrients and macronutrients (Likus-Cieślik and Pietrzykowski 2021; Zhou *et al*. 2021) [21]. Soil acidification, experience reduced pH levels, which affect nutrient availability and microbial diversity, leading to diminished soil health and crop growth (Bhat *et al*. 2025) [3]. Vehicular emissions cause soil toxicity, reducing fertility and posing risks to agricultural productivity (Luo *et al*. 2019) [9]. Deposition of the particulate matter contributes to acidification of soils, particularly when PM contains acidic components like sulphates and nitrates (Singh and Tripathi 2021) [16]. Heavy metals from the emissions leads to abnormalities in metabolic functions, impairs water balance, and affects mineral nutrition in plants. It can also cause a shortage of macronutrients like phosphorus, reducing soil productivity (Nyiramigisha *et al*. 2021) [13]. Increased level of heavy metals in soil reduces soil enzyme activities such as urease, catalase, invertase, and acid phosphatase, which are crucial for nutrient availability (Nyiramigisha *et al*. 2021) [13].
The present study aims to investigate the impact of automobile emissions on physicochemical properties of soil. Also investigate the soil organic carbon status, microbial biomass, and enzymatic activities of soil from the adjacent to the highway.

Materials and Methods
Study area: the study area was Rewari-Kotputli Highway which has heavy traffic density along, the site located near to Bawal, Rewari, Haryana India. The district Rewari of South Haryana, which lies between 29° 34' and 30° 34' north latitude and 77° 7' and 87° 12' east latitude. The altitude above sea level varies from 270 to 942 meter. In district Rewari summer rains are more frequent as compared to winter rains, so atmosphere remains humid during June to August. Best growth season in this district falls between March to May and then also between September to November each year.

Soil Sampling
Two study sites were considered for the present study, one site representing the disturbed soil because it only 5-10 m away from the highway and exposed to vehicular emission. Second one site representing undisturbed soil because it was 200 m away from the highway.
Soil samples were taken from all corners and centre of field and pooled. From upper surface of soil any unwanted material was removed using handheld hoe, then soil sample was collected from the 0-15 cm depth using tube auger. The soil samples were then put in labelled zip-lock plastic bags and taken to the laboratory for analysis.
Sampling was carried out from the fields of two different crops- Pearl millet (*Pennisetum glaucum*) and Wheat *(Triticum aestivum)* at two different period. From pearl millet field sampling was carried out at last week of June (0 DAS) and for wheat field it was carried out in last week of October (0 DAS). Second sampling was carried from the same field, from pearl millet field at 40 DAS and from wheat field at 60 DAS. Samples were dried in shade and grounded to powder and sieved to remove coarse particles.

The following physicochemical parameters (soil pH, soil electrical conductivity, N, P, K content and soil organic carbon) and biological properties (Microbial biomass, soil dehydrogenase activity and alkaline phosphatase activity) of soil were analysed. Soil pH and EC were measured electrometrically using glass electrode pH meter and Electrical conductivity meter respectively (Smith and Doran 2015) [17]. Soil organic carbon in the soil samples was estimated by wet combustion method described by (Nelson and Sommers 1996) [12] with slight modification. Available nitrogen in soil was estimated using the alkaline potassium permanganate method of Subbiah and Asija (1956) [18]. Available phosphorus in soil was estimated by the method of (Olsen 1954). Potassium was estimated by flame photometer (Jackson, 1973). Microbial biomass will be measured by plate count method from the American Public Health Association (1984). The soil dehydrogenase and alkaline phosphatase activities in soil were measured by the method of Tabatabai (1982) [19].

Results and Discussion

In the present study physicochemical and biological status of wheat and millet crop field soil under vehicular pollution were evaluated. Evaluation of soil were done at two different growth stage- for wheat field soil 0 days after sowing (DAS) and 60 DAS, whereas for millet field soil evaluation were done at 0 DAS and 40 DAS (Table 4.1 & 4.2). Crops were cultivation at two distinct locations: a control site located 200 meters away from a highway, and an experimental site situated adjacent to the roadside. The studied parameters include pH, electrical conductivity (EC), organic carbon (OC), potassium (K), phosphorus (P), nitrogen, total microbial count, dehydrogenase activity (DHA), and alkaline phosphatase (ALP) activity. The data indicates variations in soil quality and microbial activity between the two sites, which can influence wheat and millet growth and yield.

Soil sample from wheat field

The pH and Electrical Conductivity (EC)

The pH at the control site was 7.38 ± 0.17 at 0 DAS and at 60 DAS it was 7.05 ± 0.13. In comparison to control site, experimental site showed a slight decrease in pH, at 0 DAS 7.65 ± 0.24, whereas at 60 DAS 7.58 ± 0.16. The EC increased at both sites, with a more significant increase at the experimental site (from 0.66 to 0.82 dsm^{-1}). The result suggesting higher ion concentration, possibly due to contamination from vehicular emissions, dust deposition, or runoff containing pollutants.

Organic Carbon and Nutrient Content (NPK)

Soil organic carbon (OC) content was slightly higher in unaffected soil than affected soil, in the unaffected soil it was observed to be 0.35% at 0 DAS whereas 0.39% at 60 DAS. While in case of affected site soil a marked decrease in OC was observed (0.33% at 0 DAS and 0.27% at 60 DAS). The differences between OC content of affected soil and unaffected soil suggesting that the roadside environment may impair organic matter accumulation and its decomposition.

The nitrogen (N) content was declined over time in both unaffected and affected sites, but the reduction was more pronounced in the affected sites. In comparison to unaffected site a lower level of N content was observed, at affected site N content was 99.54 ± 4.36 mg/kg while at unaffected site it was 113.02 mg/kg recorded. These results indicated a greater nitrogen loss or lower microbial nitrogen cycling capacity.

Similarly, Potassium (K) level observed to be slightly increased at 60 DAS at both sites (table 4.1). However, K level was decreased in roadside soil as compared to unaffected soil. At unaffected site it was 142.14 mg/kg (0 DAS), and 151.92 mg/kg (60 DAS). In roadside soil K level was 117.32 mg/kg (0 DAS) and 119.54 mg/kg (60 DAS). The phosphorus (P) levels slightly decreased at 60 DAS at both sites. In unaffected site P level was 19.04 mg/kg (0 DAS) and 16.42 mg/kg (60 DAS) while in roadside soil P level was 16.22 mg/kg (0 DAS) and 14.24 mg/kg (60 DAS). The P level was consistently lower in the roadside soil, indicating potential nutrient leaching or reduced availability due to environmental stressors near the highway. Potassium levels were lower at the experimental site, with minimal increase over time, while phosphorus and nitrogen levels decreased at both sites, reflecting nutrient uptake by the growing wheat (Ameer *et al*., 2022).

Microbial and Enzymatic Activity

The total microbial count was higher at the control site, increasing from 20.6 x 10^6 (0 DAS) to 22.8 x 10^6 (60 DAS), compared to a slight increase at the experimental site 12.80 x 10^6 (0 DAS) to 13.00 x 10^6 (60 DAS), suggesting better microbial activity in the control soil (Hu & Qi, 2011).

Dehydrogenase (DHA) and alkaline phosphatase (ALP) activities were higher at the control site DHA was 64.52 µg TPF g^{-1}soil h^{-1} and ALP was 128.94 µg PNP g^{-1}soil h^{-1} respectively. Whereas DHA and ALP activities were decreased in road side soil 58.58 µg TPF g^{-1}soil h^{-1} and 115.14 µg PNP g^{-1}soil h^{-1} respectively. The results indicated more active soil enzyme processes, which are crucial for nutrient cycling and soil health (Hu & Qi, 2011).

While the control site shows better microbial and enzymatic activity, the experimental site maintains a more stable pH and higher EC, which could be attributed to different soil management practices, such as fertilization, that affect soil properties and wheat growth (Saeed *et al*., 2011); (Ameer *et al*., 2022).

Table 1: Physicochemical analysis of soil of wheat field at two different sites (control site 200 m away from highway and experimental site adjacent to highway).

Physicochemical parameters	Wheat Control Site: 200 m away from highway)		Wheat (Experimental Site: roadside)	
	0 DAS	60 DAS	0 DAS	60 DAS
pH	7.38 ± 0.17	7.05 ± 0.13	7.65 ± 0.24	7.58 ± 0.16
EC (dsm^{-1})	0.61 ± 0.12	0.72 ± 0.11	0.66 ± 0.05	0.82 ± 0.09
OC (%)	0.35 ± 0.02	0.39 ± 0.02	0.33 ± 0.04	0.27 ± 0.07
K (mg/kg)	142.14 ± 9.08	151.92 ± 7.76	117.32 ± 18.70	119.54 ± 24.06
P(mg/kg)	19.04 ± 2.28	16.42 ± 1.34	16.22 ± 2.22	14.24 ± 2.71
Nitrogen (mg/kg)	113.02 ± 9.27	102.76 ± 5.29	99.54 ± 4.36	94.48 ± 2.43

Total Microbial Count x 10^6	20.6 ± 2.3	22.80 ± 2.59	12.80 ± 0.84	13.00 ± 1.00
DHA Activity (µg TPF g^{-1}soil h^{-1})	64.52 ± 5.79	69.56 ± 3.48	58.58 ± 5.13	59.88 ± 0.99
ALP Activity (µg PNP g^{-1}soil h^{-1})	128.94 ± 3.53	135.38 ± 4.31	115.14 ± 6.64	116.18 ± 6.88

Soil sample from millet field

A comparative analysis of the physicochemical parameters of pearl millet grown at two different sites- a control site located 200 meters away from a highway and an experimental site situated roadside. The data is recorded at two different stages, 0 DAS and 40 DAS, highlighting variations in soil properties and microbial activity between the two sites (Table 4.2). The control site generally exhibits more favourable conditions for pearl millet growth, as indicated by the lower pH and higher organic carbon content, which are crucial for nutrient availability and microbial activity.

Soil pH and Electrical Conductivity (EC)

The pH at control sites were observed to be decreased from 7.39 to 7.11, indicating a slight acidification over time, which can enhance nutrient availability. Whereas, at experimental site, pH remained relatively stable around 7.8, suggesting less favourable conditions for nutrient uptake. An increase in electrical conductivity (EC) were observed at both sites at 40 DAS as compared to 0 DAS. The EC of control site was 0.62 at 0 DAS and 0.71 at 40 DAS, however experimental site showed higher values of EC (0.77 at 0 DAS to 0.81 dsm^{-1} at 40 DAS). The elevated EC indicated this may occurred due to roadside pollutants (Wuana *et al*. 2013) [20].

At the control sites, soil pH decreased from 7.39 to 7.11, indicating a slight trend towards acidification. This gradual decrease can be beneficial for nutrient availability, as most essential plant nutrients—such as nitrogen, phosphorus, and potassium—are optimally available in slightly acidic to neutral pH ranges (approximately 6.0–7.5) (Khaled and Sayed 2023) [7]. Acidification within this range can enhance the solubility and uptake of these nutrients, supporting plant growth. However, if pH were to drop further below 6.0, it could lead to increased solubility of toxic elements like aluminium and manganese, potentially causing plant toxicity (Khaled and Sayed 2023) [7]. Also, according to the results of other researcher's automobile emissions can increase the soil pH (Bhat *et al*. 2020 [2]; Dreshaj *et al*. 2022) [5].

Vehicular emissions contribute to the deposition of various pollutants, including salts and heavy metals onto roadside soils. The accumulation of these substances can lead to an increase in soil EC, as dissolved ions from deposited materials elevate the concentration of electrolytes in the soil solution. The experimental site, which exhibited consistently higher EC values (0.77 at 0 DAS and 0.81 ds/m at 40 DAS) compared to the control site (0.62 at 0 DAS and 0.71 ds/m at 40 DAS), may be more exposed to vehicular emissions or other sources of contamination. The finding of the present study is consistent with study by (Shannon *et al*. 2020; Bhat *et al*. 2020) [2, 14], higher soil EC near to highway and lower to away from the highway.

The experimental site's consistently higher EC values indicate greater exposure to sources of soluble salts or pollutants. If the experimental site is situated closer to a road or in an area with higher vehicular activity, this would support the hypothesis that vehicular emissions are a significant contributor to soil salinity

Organic Carbon (OC) and Nutrient Content

Soil fertility and the microbial activities are supported by the soil OC, a higher soil OC indicates high fertile field is (Habib 2021). In the present study the OC at control site was higher than roadside soil at 0 DAS. While at 40 DAS the EC level was relatively stable around 0.38 dsm^{-1} and 0.37 dsm^{-1} respectively at control and roadside soil.

The results of nitrogen level at control and roadside soil revealed control site had higher nitrogen levels than roadside soil. Although the nitrogen (N) content was improved over time (at 40 DAS) in both unaffected (118.6 mg/kg at 0 DAS to 120.66 mg/kg at 40 DAS) and affected sites (108.61 mg/kg at 0 DAS to 112.72 mg/kg at 40 DAS). Potassium (K) and Phosphorus (P) levels were higher at the control site, supporting better plant growth and development. The K level was slightly decreased at 40 DAS in control site soil than 0 DAS (149.44 mg/kg at 0 DAS to 147.28 mg/kg at 40 DAS), similarly in roadside soil its level was 136.88 mg/kg at 0 DAS and 133.98 mg/kg at 40 DAS. The P level showed slightly increase in their concentration at both site over time, in control site soil P level was 20.08 mg/kg at 0 DAS and 21.44 mg/kg at 40 DAS. While its concentration was increased from 17.12 mg/kg at 0 DAS to 19.14 mg/kg at 40 DAS.

Pollutants from the vehicular emissions are hazardous to vegetation located near highway which led to changes in the biogeochemical processes in the soil and impacted on the ecosystem and plant community and reduced bioaccumulation. Our results are in the same direction with the findings of (Bhat *et al*. 2020 [2]; Dreshaj *et al*. 2022 [5]; Donchev *et al*. 2023) [4] who reported a decrease in the SOC level in roadside soil as compared to the control soil.

The levels of nitrogen (N), phosphorus (P), and potassium (K) in soils near highways are significantly influenced by vehicular pollution and fertilizer application practices. Research indicates that roadside soils often exhibit nutrient depletion due to contamination and environmental factors (Mir *et al*. 2020) [11]. The soil nitrogen level decline in roadside soil of both crop fields, however, in wheat field it slightly increases overtime and in millet field it decreases overtime (Table 1 & 2). The phosphorous level decline in roadside soil of both crops, however, in wheat field it slightly increases overtime and in millet field it decreases overtime (Table 1 & 2). Potassium level also gradually decreased in soils of both crop fields adjacent to roadside soil. However, potassium level was increased overtime in wheat field and slightly decreased overtime in pearl millet field (Table 1 & 2).

The increase in P could be due to mineralization, fertilizer input, or reduced plant uptake relative to release from soil organic matter (Mabagala and Mng'ong'o 2022) [10]. However, the consistently lower P at the roadside site may result from pollutant-induced changes in soil pH, reduced microbial activity, or the binding of P to heavy metals and other contaminants from vehicular emissions (Angon *et al*.2024) [1].

The reduced nitrogen concentration at 40 DAS, relative to 0 DAS, may be attributed to lower nitrogen mineralization resulting from a reduction in labile organic matter, microbial activity, and the accumulation of toxic substances over the time (Sheoran *et al*. 2025) [15]. These results of nutrient level

(NPK level) agreed with findings of previous studies (Gupta *et al*. 2013; Singh *et al*. 2018 [16]; Mir *et al*. 2020 [11]; Sheoran *et al*. 2025) [15].

Microbial Activity and Enzymatic Functions

Total microbial count was higher at the control site, indicating a more active soil microbial community, which is essential for nutrient cycling (Ndour *et al*., 2021 https://doi.org/10.1007/S11104-021-04917-W). The microbial count at control site was 24 x 10^6 (0 DAS) and 28.2 x 10^6 (40 DAS). The microbial count in roadside soil was 21.40 x 10^6 (at 0 DAS) and 22.60 x 10^6 (at 40 DAS). Dehydrogenase (DHA) and alkaline phosphatase (ALP) activities were higher at the control site, reflecting better soil health and nutrient availability. Both enzymes' activities were improved over time. The DHA activity in control site soil was 71.96 µg TPF g^{-1}soil h^{-1} at 0 DAS and 81.02 µg TPF g^{-1}soil h^{-1} at 40 DAS, similarly in roadside soil its activity at 0 and 40 DAS were 59.20 and 60.42 µg TPF g^{-1}soil h^{-1} respectively.

A significant difference in ALP activities in control soil and roadside soil were observed, also a significant difference between 0 DAS and 40 DAS were found in control and roadside soil. In control soil at 0 DAS ALP was 133.77 µg PNP g^{-1}soil h^{-1} and at 40 DAS its activity was 140.00 µg PNP g^{-1}soil h^{-1}, whereas, in roadside soil at 0 DAS ALP activity was 126.48 µg PNP g^{-1}soil h^{-1} and at 40 DAS ALP was 129.90 µg PNP g^{-1}soil h^{-1}).

While the control site shows more favourable conditions for pearl millet growth, the experimental site's proximity to the highway may introduce pollutants that affect soil properties and plant health. This highlights the importance of site selection and environmental factors in agricultural productivity and soil management strategies (Darghan *et al*., 2021)

Table 2: Physicochemical analysis of soil of Pearl Millet field at two different sites (control site 200 m away from highway and experimental site adjacent to highway).

Physicochemical parameters	Pearl Millet (Control Site: 200 m away from highway)		Pearl Millet (Experimental Site: roadside)	
	0 DAS	40 DAS	0 DAS	40 DAS
pH	7.39 ± 0.11	7.11 ± 0.14	7.84 ± 0.28	7.81 ± 0.34
EC (dsm^{-1})	0.62 ± 0.09	0.71 ± 0.05	0.77 ± 0.02	0.81 ± 0.03
OC (%)	0.37 ± 0.06	0.38 ± 0.03	0.30 ± 0.06	0.37 ± 0.03
K (mg/kg)	149.44 ± 12.03	147.28 ± 14.75	136.88 ± 17.17	133.98 ± 23.60
P(mg/kg)	20.08 ± 4.1	21.44 ± 1.89	17.12 ± 0.66	19.14 ± 1.32
Nitrogen (mg/kg)	118.6 ± 8.09	120.66 ± 6.59	108.61 ± 13.36	112.72 ± 11.88
Total Microbial Count x 10^6	24.0 ± 2.12	28.20 ± 1.48	21.40 ± 2.30	22.60 ± 1.67
DHA Activity (µg TPF g^{-1}soil h^{-1})	71.96 ± 5.89	81.02 ± 2.40	59.20 ± 7.11	60.42 ± 3.70
ALP Activity (µg PNP g^{-1}soil h^{-1})	133.77 ± 17.7	140.00 ± 14.73	126.48 ± 6.59	129.90 ± 6.96

Vehicular pollution negatively impacted on the Microbial biomass and enzymatic activities. However, progression in both crop at both sites supported microbial growth at some extent. In wheat field, in control soil more than 11% increase in microbial count after 60 DAS, whereas, in pearl millet field in its count was increased with 18% over time. In roadside soil of wheat field microbial count increased only with 3% overtime and in pearl millet field growth was 6% overtime. Enzymes, DHA and ALP activities were also affected by emissions, its activities decrease in roadside soil (table 1 & 2).

Soil enzymatic activity has been identified as a more sensitive bio-indicator of natural and human disturbances than plants and animals (Bhat *et al*. 2025) [3]. These results were found in concordance with results of (Li *et al*. 2015; Jaworska and Lemanowicz 2019 [6]; Bhat *et al*. 2025) [3]

Conclusions

The findings of the present study suggest that highway proximity alters key soil parameters, potentially impacting crop productivity and long-term soil fertility. Monitoring and mitigation strategies are essential to preserve soil health in areas subjected to vehicular pollution.

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