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Biochemical Changes in Leaves and Physico-chemical Alterations in Rhizospheric soil of Selected Trees Exposed to Vehicular Pollution at Roadsides at Jabalpur, India

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

In many South-Asian countries like India, the metropolitan areas get exposed to high air-pollution due to emissions from vehicles driven by the fossil fuels. This research was aimed to detect the effect of dust and gases from automobile exhausts on foliar biochemical changes of roadside vegetation and in physico-chemical properties of soil at Jabalpur, India. Considering the samples collected from least polluted areas as control set with distinction from roadsides of higher air-pollution as experimental, biochemical analyses from tender leaves were done from five pollution-resistant trees viz. *Pongamia pinnata, Dalbergia sissoo, Azadirachta indica, Ficus religiosa* and *Cassia siamea* for total carbohydrate, nitrogen, calcium, sodium, potassium, magnesium, phosphorus, ascorbic acid and phenol. Between the control and experimental samples, for few

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parameters like sodium and potassium assays, minimum differences in values were found, while for the others, remarkable differences were evident, which might have been happened due to physiological processes like damage-due-to-air-pollutants or resistance-and-protection-to-air-pollutants or for the both. For rhizospheric soil, physico-chemical analyses were done for pH, bulk density, electrical conductivity, cation-exchange capacity, organic carbon, available nitrogen, available potassium, available phosphorus, exchangeable potassium, exchangeable sodium, exchangeable calcium and exchangeable calcium and magnesium. All results both for foliar and soil analyses were expressed as mean values in replicates of 3 samples. Amongst the interesting findings, the following were noted like the pH was found to be higher in *Pongamia pinnata, Azadirachta indica* and *Ficus religiosa,* the available nitrogen higher in *Pongamia pinnata, Ficus religiosa* and *Cassia siamea* in the polluted samples. For some important individual elements and compounds, the findings have provided a index-guideline indicating their absorption and assimilation with the nutrient molecules. The findings are significant in relating plantation-schedules and monitoring programs in many crowded and polluted cities in tropical South Asian countries.

Keywords: Pollution; resistant trees; automobile exhausts; Pongamia pinnata; Dalbergia sissoo; Azadirachta indica; Ficus religiosa; Cassia siamea.

1. INTRODUCTION

Jabalpur is an important city of MP, India, situated almost at centre of India, latitude being N+23°10’00’’, longitude E+79°56’60.00’’ and altitude 393 meter from the sea level; population 1,117,200 (2001 Census), per capita income being almost Indian Rupees 30,000/-. Jabalpur is one of the polluted cities in MP, where perhaps no study has been conducted so far on the effect of general air pollution, dust, more specifically of automobile exhaust on the composition of road side rhizospheric soil. This study was carried out to detect some of the effect of dust and gases from automobile exhausts on physicochemical properties of soil and biochemical changes on roadside vegetation.

Air pollution is a major part of the overall atmospheric pollution and the motor vehicle emissions usually constitute the most significant source of ultra-fine particles in an urban environment [1,2]. Important chemical pollutants emitted by land vehicles are carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and total suspended particles (TSP). The smoke is a mixture of particles and gaseous chemicals of varying physical and chemical properties.

1.1 Exhaust Emission Pollutants

The six major air pollutants prevailing in any polluted city are carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), particulate matter (PM-10) and lead (Pb). Out of these, carbon monoxide, hydrocarbons and oxides of nitrogen are pollutants prevalent in automobile exhaust. Ozone (O_3) is produced through a complex series of chemical reactants that result from pollutants (HC and NO_X). Mixing in the atmosphere in the presence of sunlight, ozone concentrations are highest in urban centers and downwind of urban.

On road vehicles like vehicle miles of travel (VMT) (Like buses, trucks) auto ownership, personal trips, and fractions of single occupant vehicles (SOV) have been significantly contributed to air pollution. Today’s growing population and increasing urbanization has resulted in sudden increase in the number of vehicles, which discharge lots of pollutants; more than 60% air pollution in city is caused by automobiles only [3]. Trees / rhizospheric soil were considered for investigation of effect of auto exhaust pollutant.

1.2 The Mechanics of Exhaust Emissions

In ideal combustion, oxygen and fuel (HC) are combusted and produce byproduct emissions of carbon dioxide (CO_2) and water (H_2O). Air, however, contains nitrogen (N_2) among other chemicals, and combustion is always incomplete, producing byproducts of HC, CO, Oxygen (O_2), Carbon dioxide (CO_2), water (H_2O) and NOx.. The air to fuel ratio is an important factor in determining the quantity of pollutants produced by combustion. Generally, rich fuel mixtures produce high amounts of CO and HC because combustion is incomplete. Lean fuel mixtures (high a/f ratios) will typically produce higher amounts of NOx (especially during very hot, lean conditions) and lower amount of CO and HC because combustion is more complete. When considering vehicle activity, high power demand (sharp accelerations, heavy loads etc.) creates a rich fuel mixture resulting in elevated CO and HC emission rates while NOx generally decreases. At high speeds with low accelerations rates, a lean fuel mixture develops which increases NOx emissions rates (Fig. 1).

The four, six and eight cylinder engines used in motor vehicles make certain demands on gasoline which are mostly determined by the engine construction. In the first place, the gas must form a highly homogeneous and highly flammable mixture with air it needs for combustion. This mixture of fuel and air must also have a low change of igniting spontaneously. That is, it must have a high octane rating. If the octane rating is low, the fuel and air mixture can ignite prematurely and disturb the smooth running of the engine and cause knocking. Until recently, the octane rating of gasoline was normally raised by the addition of lead in concentration of between 0.3 and 0.6 grams per liter, despite the unfavorable effects [4] it had on the environment (Fig. 2).

1.3 Diesel

Diesel or Diesel fuel is a specific fractional distillate of fuel oil (mostly petroleum) that is used as fuel in a diesel engine invented by German engineer Rudolf Diesel. The term typically refers to fuel that has been processed from petroleum, but increasingly, alternatives such as bio- diesel or biomass to liquid (BTL) or gas to liquid (GTL) diesel that are not derived from petroleum are being developed. Petroleum derived diesel is composed of about 75% saturated hydrocarbons (primarily paraffins including *n*, *iso*, and cycloparaffins), and 25% aromatic hydrocarbons (including naphthalenes and alkylbenzenes). Diesel is produced from petroleum, and is sometimes called petro-diesel (or, less seriously, dino-diesel) when there is a need to distinguish it from diesel obtained from other sources. As a hydrocarbon mixture, it is obtained in the fractional distillation of crude oil between 250℃ and 350℃ at atmospheric pressure. Petro Diesel is considered to be a fuel oil and is about 18% denser than gasoline.

Diesel typically weighs about 7.1 pounds (lb) per US gallon (gal) (850 grams per liter (g/l)), whereas gasoline weighs about 6.0 lb per US gal (720 g/l), or about 15% less. When burnt diesel typically releases about 147,000 British thermal units (BTU) per US gal (40.9 megajoules (MJ) per liter), whereas gasoline releases 125,000 BTUs per US gal (34.8 MJ/l), also about 15% less. Diesel is generally simpler to refine than

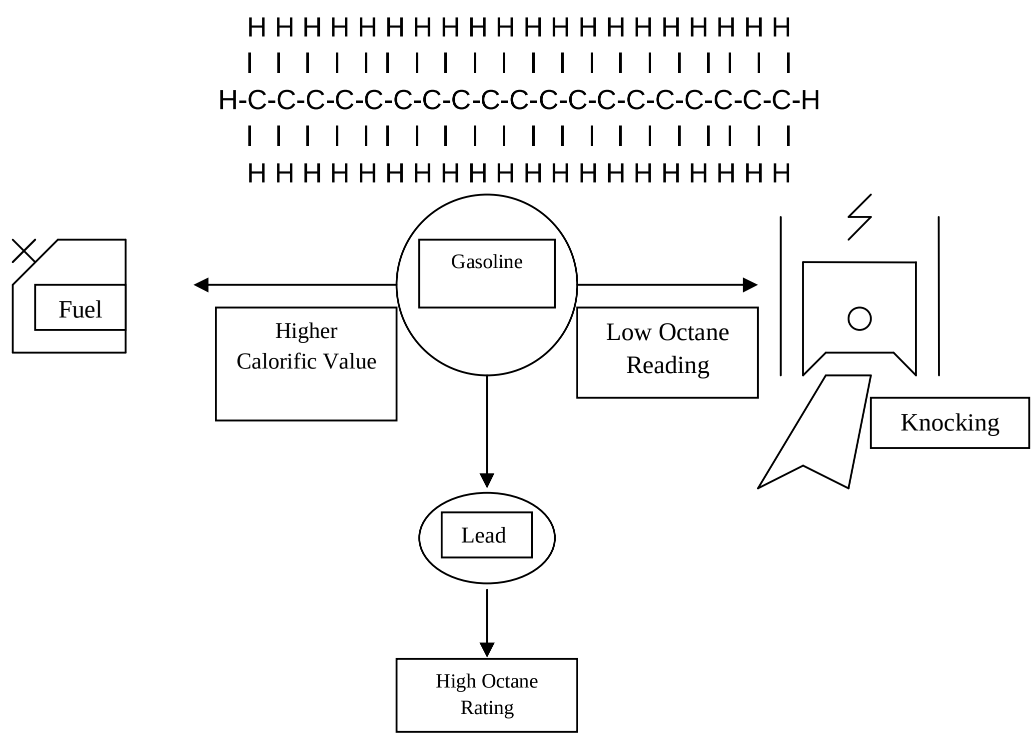

Fig. 1. Properties of gasoline

gasoline and often costs less (although price fluctuations often mean that the inverse is true; for example, the cost of diesel traditionally rises during colder months as demand for heating oil, which is refined much the same way, rises).

Diesel fuel, however, often contains higher quantities of sulfur. In Europe, emission standards and preferential taxation have both forced oil refineries to dramatically reduce the level of sulfur in diesel fuels. In contrast, the US has long had "dirtier" diesel having a lower cetane number (a measure of ignition quality) resulting in worse cold weather performance and some increase in emissions, although more stringent emission standards have been adopted with the transition to ultra-low sulfur diesel (ULSD) occurring in 2006.

High levels of sulfur in diesel are harmful for the environment. It prevents the use of catalytic diesel particulate filters to control diesel particulate emissions, as well as more advanced technologies, such as nitrogen oxide (NOx) adsorbers (still under development), to reduce emissions. However, lowering sulfur also reduces the lubricity of the fuel, meaning that additives must be put into the fuel to help lubricate engines. Bio-diesel is an effective lubricity additive. Diesel contains approximately 18% more energy per unit of volume than gasoline, which, along with the greater efficiency of diesel engines, contributes to fuel economy (Distance traveled per volume of fuel consumed).

1.4 Petrol

Petrol is extracted from crude oil and there are many derivatives which are extracted from crude oil. Diesel, Kerosene, LPG, CNG, White kerosene (aviation fuel), petrol, ethanol, methanol to name a few. The OPEC (Organization of the Petroleum Exporting Countries) estimates that there is enough crude oil in the world to last another 80 years. The normal unleaded petrol you use has an octane rating of 87 or higher. The other octane petrol available in India are 91, 93, 97 RON octane respectively. Petrol is made up of aliphatic and aromatic hydrocarbons along with toluene and benzene. In this, toluene is an explosive and it is used as TNT (trinitrotoluene) in explosives. That’s why petrol is highly inflammable and can explode when it comes in contact with fire. Benzene and Toluene are added to increase the octane rating.

The higher the octane rating the greater the resistance of petrol to explosion, which is why all high performance engines need high octane fuels. High performance engines have high compression ratios compared to normal engines because they produce more power and are high revving. The higher the compression ratio the more efficient the engine is. An example we have is the use of only speed 97-octane petrol for the R1, Hayabusa and racecars in India else their engines wouldn’t perform optimally due to loss of power.

1.5 Difference between Diesel and Petrol

Both Diesel and petrol are liquid fractions with different composition of hydrocarbons and difference in boiling range. Petrol, being more volatile and less abundant fraction has wider applications than the less volatile larger fraction, diesel. Further fractionated petrol is used in aero plane with higher cost. The loss on storing, transport etc too is more for the petrol than diesel.

Diesel is a cetane fuel and works in a compression ignition engine where the fuel air mixture is compressed to such an extent that it burns. Cetane fuels burn in gradual layers and produce sustained power. Running of a heavy duty truck, water pump, or tractor are the ideal jobs for a diesel engine. A Petrol or Octane engine requires an external spark to ignite the fuel air mixture which is known as a spark ignition engine .Octane fuels burn or explode with the entire fuel air mixture catching fire almost simultaneously. This provides petrol engines with much better pick up for other similar characteristics. However the designing of a diesel engine is much more complex. Cost of producing both fuels is comparable but lower taxes on diesel make it cheaper in India.

The initial emissions from the automotives are the gaseous and particulate pollutants, and these air-toxics are found in high amount in atmosphere. The burning of petrol and diesel in the automotive engines generates many toxic molecules. There remain multiple origins for the carbon and metal compounds, like refueling-emissions, spills on heated engines, tailpipe-emissions, abrasion and wear of tyres and metallic components.

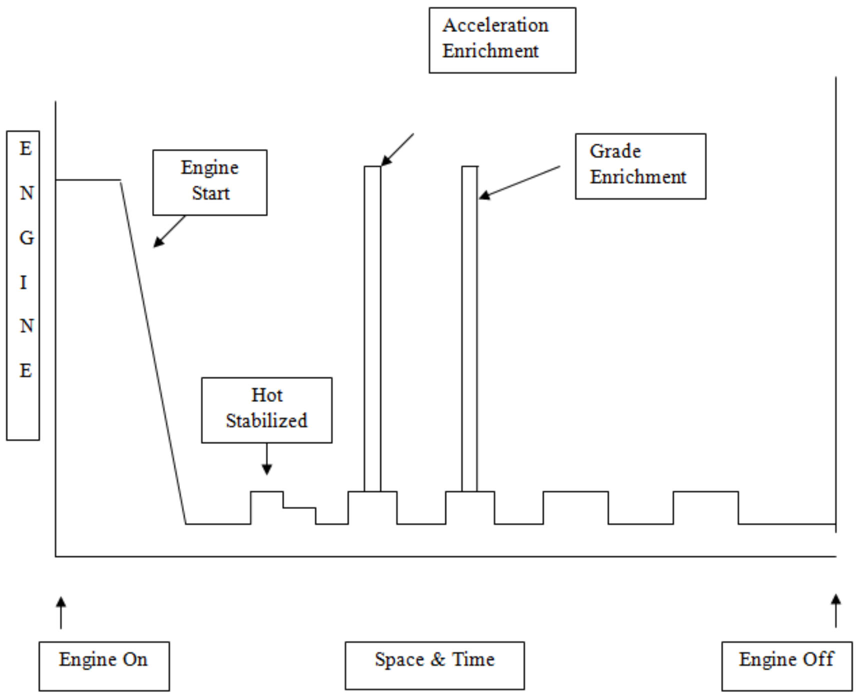

Fig. 2. CO emissions for a hypothetical vehicle trip

1.6 Emission from Internal Combustion of Engine

The contaminants discharged to the atmosphere from fuel burning, incineration of refuse and internal combustion engine are as follows:

- Particulate matter (PM_{10} and $PM_{2.5}$ [particles <10 μm and <2.5 μm in aerodynamic diameter, respectively)
- Sulfur dioxide
- Natural gas
- Exhausts from engine include CO, Oxides of Nitrogen, Hydrocarbons, Oxygenates of hydrocarbons, Lead compounds, Carbon particles, Aldehydes (Acetaldehyde, Formaldehyde), Benzene, 1,3-Butadiene, Motor oil, Non-volatile reaction products and a large number of substances identified as Polycyclic Organic Matters including Polycyclic Aromatic Hydrocarbons (PAHs) formed from motor oil in the combustion zone. High molecular weight of olefines and carbonyl compounds are produced in the reactions.

The amount of above products depends upon the compositions of fuel method of firing and other factors [5] (Tables - 1, 2 and 3).

Table 1. Emission factors for uncontrolled automobile exhaust

Type of emission	Emission pounds per 1000 Vehicle-Miles	Pounds per vehicle day
Particulates	0.8	0.022
Organic acids (acetic)	0.3	0.007
Oxides of sulfur (SO_2)	0.6	0.016
Oxides of Nitrogen (NOx)	8.5	0.202
Hydrocarbons (CxHv)	12.5	0.363
Carbon monoxide (CO)	165.0	4.160
Aldehydes (HCHO)	0.3	0.007

Source: Agarwal [1]

Table 2. Emission factors for diesel engines (Pounds per 1000 gallons of diesel fuel)

Type of emission	Emission factor
Particulates	110
Organic acids (acetic)	31
Oxides of sulfur (SO_2)	40
Oxides of nitrogen (NOx)	222
Hydrocarbons (CxHv)	136
Carbon monoxide (CO)	60
Aldehydes (HCHO)	10

Source: Agarwal [1]

The following study was conducted for physicochemical assessment of the effect of pollution, with special reference to automotive exhausts at busy road-sides at Jabalpur, on the-root-associated or rhizospheric soil of some pollution-resistant trees and on the leaves of some pollution-resistant trees.

2. MATERIALS AND METHODS

Rhizospheric or root associated soils and fresh leaves were collected by summer time (April - May 2009, atmospheric temperature 40 - 42ºC) with the help of crow-bar and khurpi from the busy roadside of Jabalpur, namely Sadar Bazar, Indira Market and Raddi Chowk. One tree was sampled from each of the area, and the control trees were sampled from nursery of the Tropical Forest Research Institute where it is expected that the effect of pollution is minimal. The tree species were carefully chosen, which were found to be resistant at Korba, Talcher and Raigarh industrial areas as described by our laboratory group earlier [6,7,8,9]. The resistant tree species selected for this exhaustive study were *Pongamia pinnata*, *Dalbergia sissoo*, *Azadirachta indica*, *Ficus religiosa*, *Cassia siamea.*

The number of the passing vehicles was counted physically in between 10.30 am to 11.30 am when the frequency of fueled vehicles is found maximum on road as the first business hour. The counting was done once in a week consecutively for 3 weeks during April - May 2016 at the 3 points at Jabalpur as described above which indicates the magnitude of height of automobile pollution at the said roadside points (Table 3), ~1247 diesel / petrol fueled vehicles per hour, means ~21 vehicles per minute.

2.1 Rhizospheric Soil Analysis

All samples of surface-soil were collected from 4 inches depth. pH, bulk density, electrical conductivity, cation exchange capacity, organic matter, available nitrogen, available potassium, available phosphorus, exchangeable potassium, exchangeable sodium, exchangeable calcium, exchangeable combined calcium and magnesium were estimated as described by Sadasivam and Manickam [10].

2.2 Foliar Analysis

Tender leaves were collected for the assays. H_2O_2 digestion method was followed for estimation of total potassium, total calcium, total magnesium, total phosphorus and total sodium as described by Sadasivam and Manickam [10]. Total nitrogen, ascorbic acid, chlorophyll a, chlorophyll b, total chlorophyll, phenol and carbohydrate were estimated as described by Sadasivam and Manickam [10].

3. RESULTS

The results of different parameters for rhizospheric soil analysis are shown below from Figs. 3a to 14b, where 'Control' and 'Polluted' have been assigned as C and P, Bulk Density as 'BD', Electrical Conductivity as 'EC', Organic Carbon as 'OC', Available Nitrogen as 'Av. N.', Available Potassium as 'Av. K', Available Phosphorus as 'Av. P.', Exchangeable Potassium as 'Ex. K', Exchangeable Sodium as 'Ex. Na' and Exchangeable Calcium as 'Ex. Ca' in the figures. Data presented here are mean of 3 replicates for each parameter. The results of different parameters for foliar analysis are shown below from Tables 4 to 15. The resistant tree species selected for this exhaustive study were *Pongamia pinnata*, *Dalbergia sissoo*, *Azadirachta indica*, *Ficus religiosa*, *Cassia siamea*.

Table 3. Frequency of fueled vehicles per hour between 10.30 – 11.30 am at Jabalpur (data presented as mean of 3 hour counts in consecutive 3 weeks)

Car	Auto rickshaw	Truck	Bike	Bus	Pick-up van	Total
266	97	8	815	14	47	1247

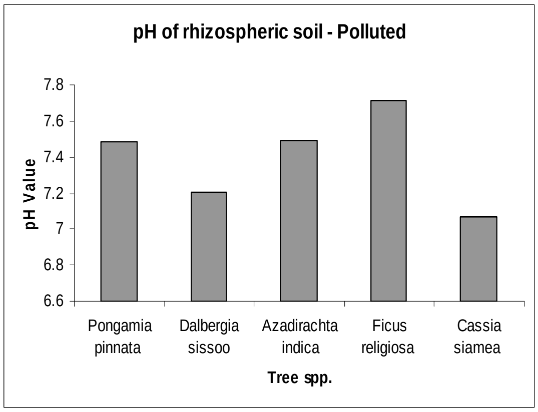

Fig. 3a. pH of rhizospheric soil (P)

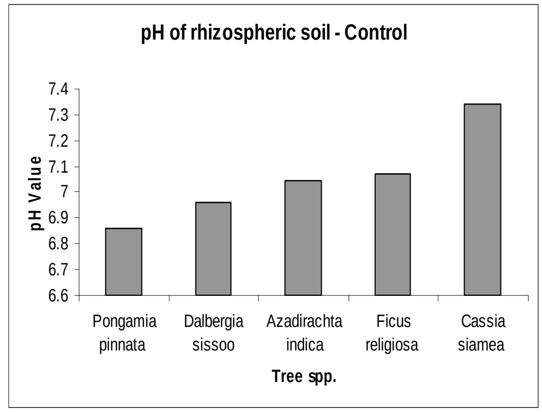

Fig. 3b. pH of rhizospheric soil (C)

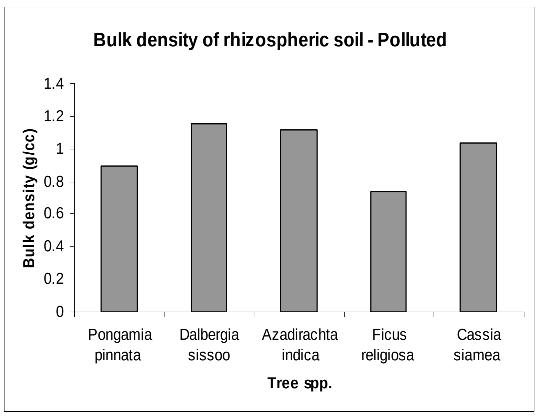

Fig. 4a. BD of rhizospheric soil (P)

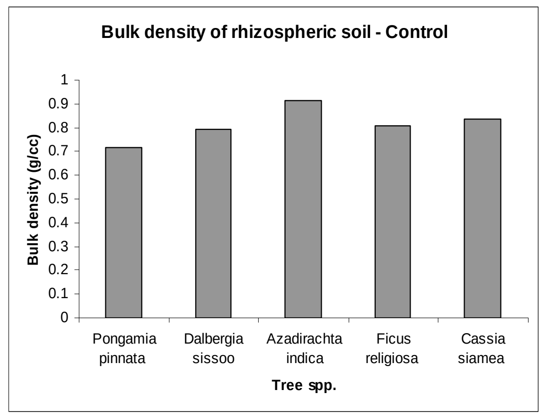

Fig. 4b. BD of rhizospheric soil (C)

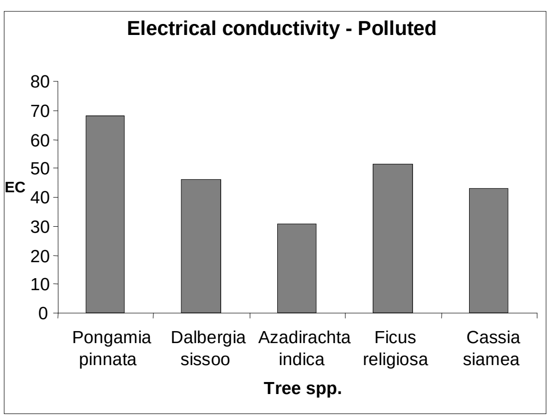

Fig. 5a. EC of rhizospheric soil (P)

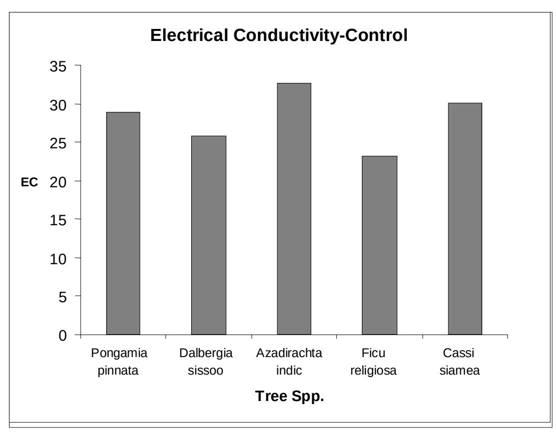

Fig. 5b. EC of rhizospheric soil (C)

4. DISCUSSION

The utilization of plant species for controlling roadside pollution is a matter of much concern today for the common people [11,12]. Researchers have quantified the heavy metal content in the surface and subsurface soils in the roadsides [13,3,4]. A summary of automotive exhaust levels has been furnished in Table 14. In a recent study, Mate and Deshmukh [12] have analyzed the toxic effects of particular matter, hydrocarbons, nitrogen oxides, carbon monoxide, sulphur dioxide, other toxins and greenhouse gases in the leaves of *Azadirachta indica*, *Polyalthia longifolia*, *Ficus bengalensis*, *Mangifera indica*, *Acacia arabica* and *Peltophorum pterocarpum*. In Asian countries, likewise studies have also been reported by other workers [5,14,15,16].

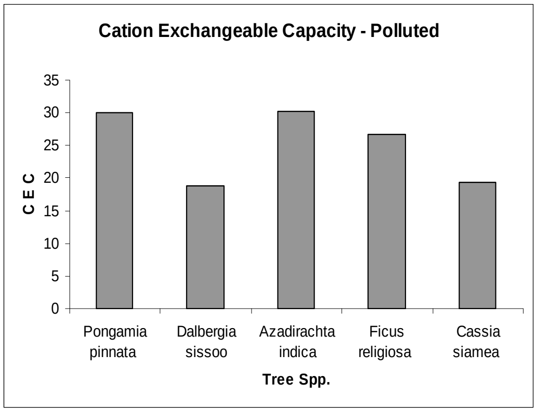

Fig. 6a. CEC of rhizospheric soil (P)

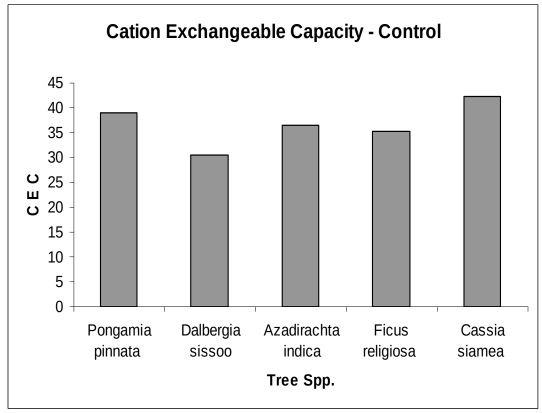

Fig. 6b. CEC of rhizospheric soil (C)

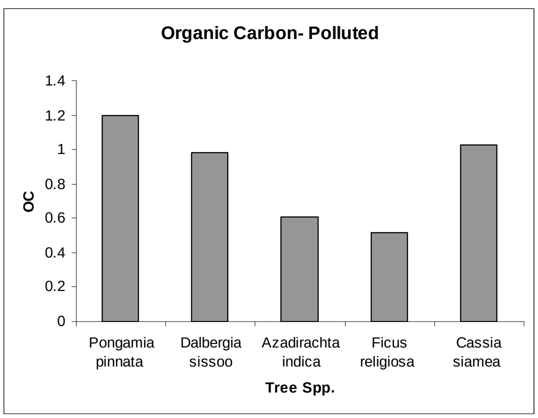

Fig. 7a. OC of rhizospheric soil (P)

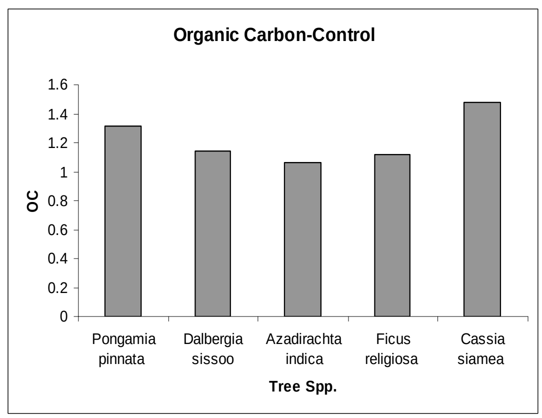

Fig. 7b. OC of rhizospheric soil (C)

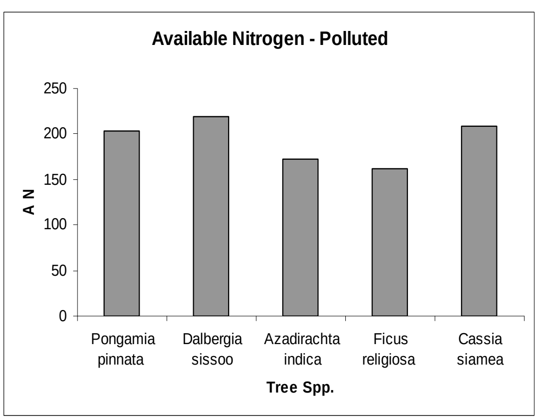

Fig. 8a. Av. N of rhizospheric soil (P)

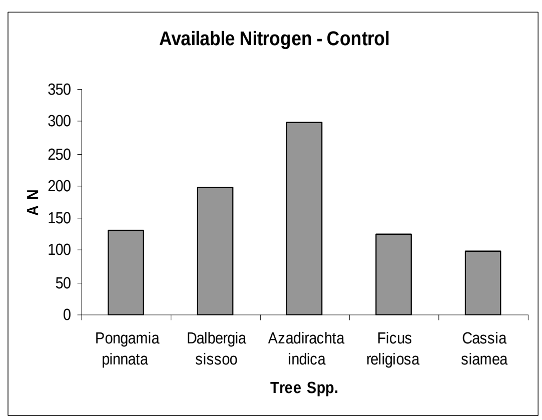

Fig. 8b. Av. N of rhizospheric soil (C)

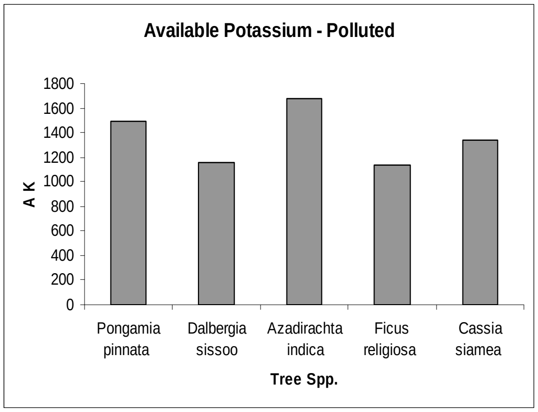

Fig. 9a. Av. K of rhizospheric soil (P)

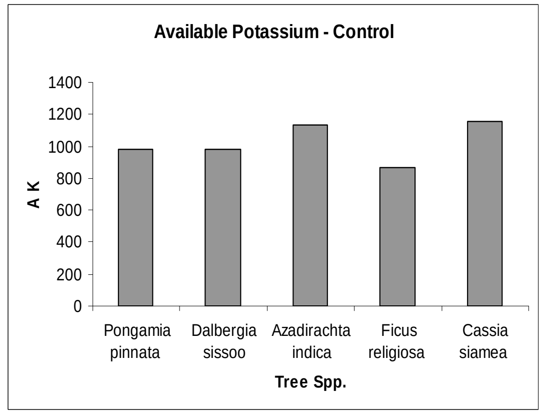

Fig. 9b. Av. K of rhizospheric soil (C)

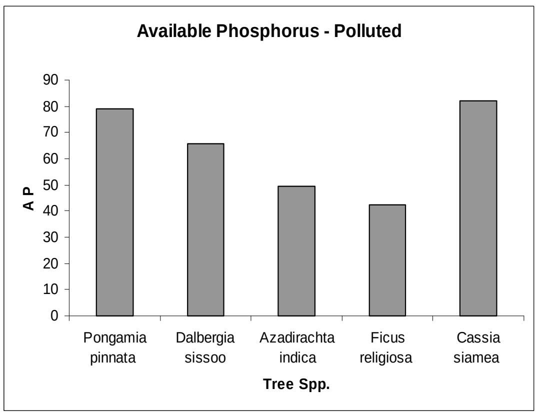

Fig. 10a. Av. P of rhizospheric soil (P)

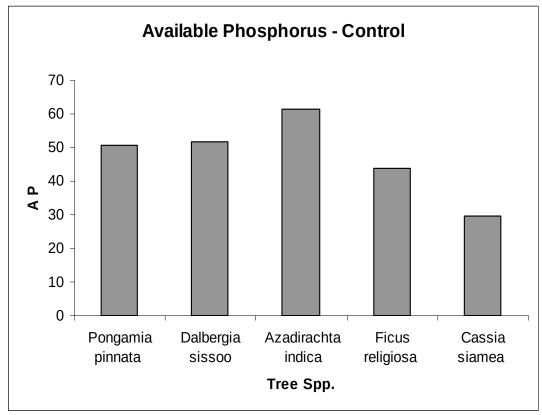

Fig. 10b. Av. P of rhizospheric soil (C)

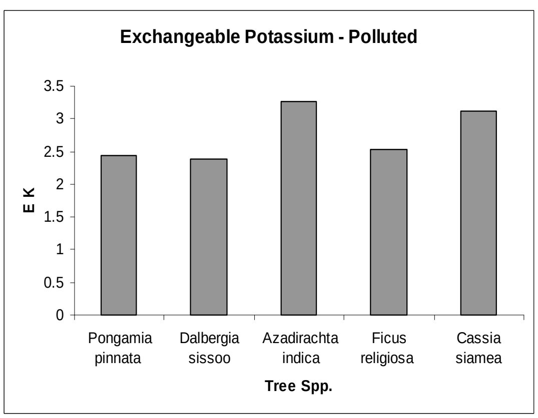

Fig. 11a. Ex. K of rhizospheric soil (P)

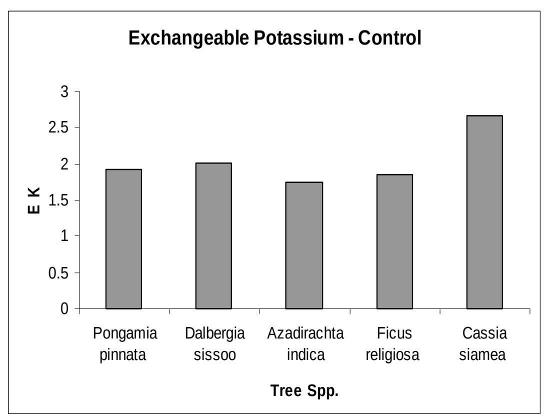

Fig. 11b. Ex. K of rhizospheric soil (C)

Generally, it is expected that the pH of soil of highly polluted and disturb area may be found more acidic than the undisturbed one [17], but surprisingly, it was evident from result that, except that of *Cassia siamea,* the pH of all the rhizospheric soil of the remaining 3 tree species in the polluted area was higher than the controls, rather in the slightly alkaline range from 7.2 to 7.6, which may indicate some root associated unknown reaction which may enhance the pH of the soil; perhaps this mechanism is unique for the resistant trees to enable them to thrive.

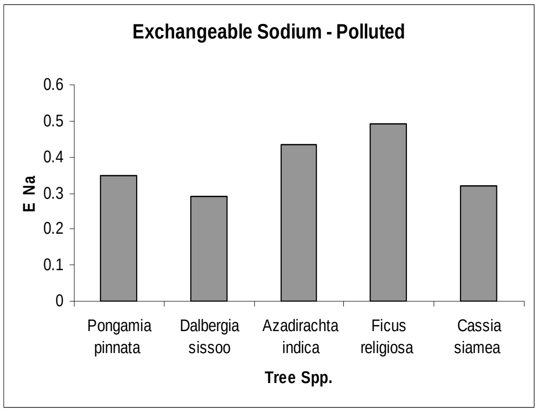

Fig. 12a. Ex. Na of rhizospheric soil (P)

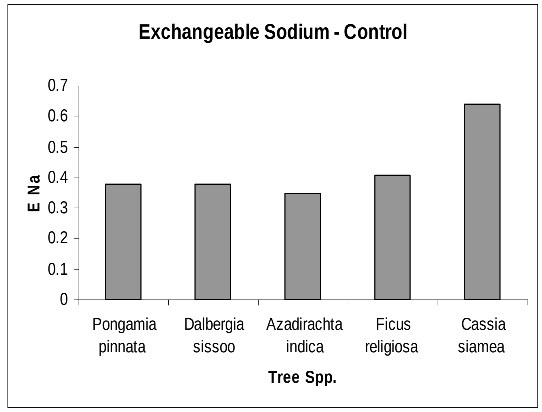

Fig. 12b. Ex. Na of rhizospheric soil (C)

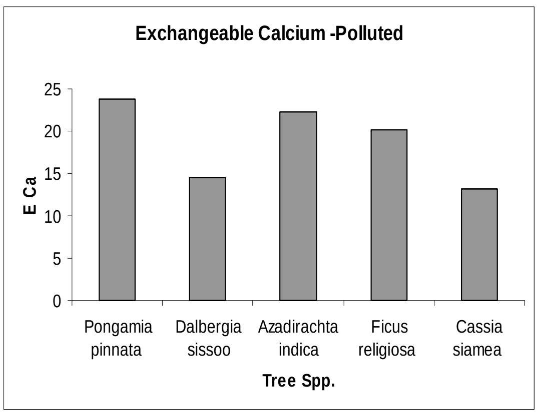

Fig. 13a. Ex. Ca of rhizospheric soil (P)

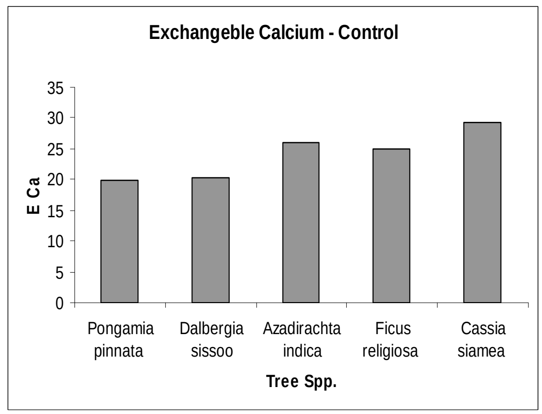

Fig. 13b. Ex. Ca of rhizospheric soil (C)

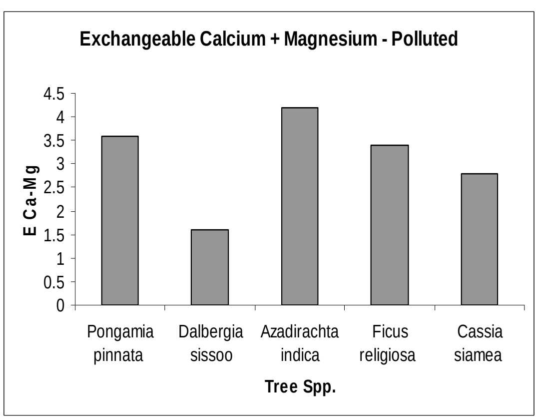

Fig. 14a. Ex. Ca+M of rhizospheric soil (P)

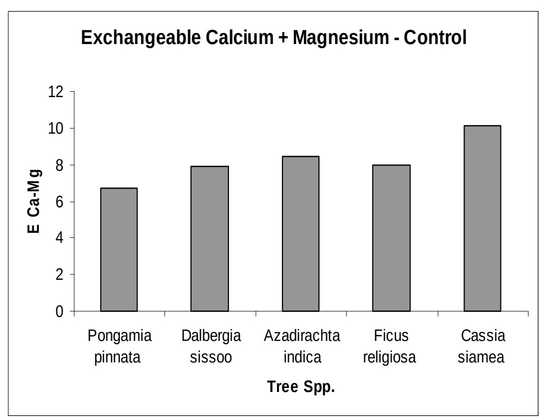

Fig. 14b. Ex. Ca+M of rhizospheric soil (C)

Regarding the estimation of bulk density, no significant difference was noticed. Regarding the measurement of electrical conductivity, it was found that the EC of the rhizospheric soil in the polluted area was higher than the control as expected at par with the results of other workers.

The cation exchange capacity or CEC was found little lower in the rhizospheric soil of the resistant tree species which does not match the normal phenomenon and indicate, that like that of reversing the pH phenomenon, the cation exchange capacity in the rhizospheric soil of the resistant tree species was somehow modified / rectified by the tree root-associated micro-system towards normality for enhanced absorption of nutrients molecules.

Table 4. Levels of total ascorbic acid in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	0.03098 ± 0.004242	0.0193 ± 0.0023
2.	*Dalbergia sissoo*	0.02517 ± 0.001477	0.0193 ± 0.0023
3.	*Azadirachta indica*	0.10650 ± 0.005877	0.0270 ± 8.9964
4.	*Ficus religiosa*	0.02905 ± 0.00821	0.0173 ± 0
5.	*Cassia siamea*	0.06000 ± 0.002094	0.2265 ± 0.1847

Table 5. Level of total carbohydrate in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	9.800 ± 8.7517	10.3438 ± 6.2675
2.	*Dalbergia sissoo*	17.693 ± 4.3248	26.7151 ± 5.3657
3.	*Azadirachta indica*	6.4163 ± 2.32151	14.1158 ± 8.7479
4.	*Ficus religiosa*	7.2912 ± 4.2068	20.1238 ± 3.8770
5.	*Cassia siamea*	11.8599 ± 6.0976	9.8383 ± 6.2675

Table 6. Level of total phenol in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	6.14 ± 2.9263	5.259 ± 1.6339
2.	*Dalbergia sissoo*	6.443 ± 1.2237	6.039 ± 1.7823
3.	*Azadirachta indica*	5.57 ± 2.1729	4.636 ± 11.082
4.	*Ficus religiosa*	7.96 ± 4.7093	3.489 ± 0.7778
5.	*Cassia siamea*	5.75 ± 1.3851	7.75 ± 1.5989

Table 7. Level of total chlorophyll-a in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	0.9455 ± 0.39051	1.1854 ± 0.6075
2.	*Dalbergia sissoo*	1.1918 ± 0.6606	0.5520 ± 0.2745
3.	*Azadirachta indica*	1.1395 ± 0.6375	1.2123 ± 0.6582
4.	*Ficus religiosa*	0.7626 ± 0.2091	0.6979 ± 1.0423
5.	*Cassia siamea*	1.5542 ± 0.4469	1.4446 ±0.3503

Table 8. Level of total chlorophyll-b in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	0.3773 ± 0.1466	0.796 ± 0.4287
2.	*Dalbergia sissoo*	0.7595 ± 0.4288	0.267 ± 0.1769
3.	*Azadirachta indica*	1.5006 ± 1.0562	1.8329 ± 0.8779
4.	*Ficus religiosa*	1.2093 ± 0.08300	0.2932 ± 0.1483
5.	*Cassia siamea*	3.7831±5.0558	0.7225 ± 0.2903

Table 9. Level of total chlorophyll in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	5.5166 ± 7.3459	0.174 ± 0.08712
2.	*Dalbergia sissoo*	0.5985 ± 2.4156	0.5744 ± 0.3293
3.	*Azadirachta indica*	0.8928 ± 0.51210	1.2490± 0.6788
4.	*Ficus religiosa*	0.3353 ± 0.2524	0.9893± 0.5902
5.	*Cassia siamea*	2.3157 ± 0.3827	2.1671±0.5786

Table 10. Level of total magnesium in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	0.16 ± 0.06928	0.312 ± 0.3412
2.	*Dalbergia sissoo*	0.385 ± 0.42	0.568 ± 0.1091
3.	*Azadirachta indica*	0.48 ± 0.4326	0.56 ± 0.3666
4.	*Ficus religiosa*	0.42 ± 0.2683	1.26 ± 0.0848
5.	*Cassia siamea*	0.68 ± 0.5670	7.75 ± 0.3857

Table 11. Level of total calcium in leaves of Control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	1.63 ± 0.4041	2.066 ± 0.6077
2.	*Dalbergia sissoo*	1.33 ± 0.13241	1.27 ± 0.6429
3.	*Azadirachta indica*	1.2 ± 0.5291	1.04 ± 0.2083
4.	*Ficus religiosa*	4.7 ± 0.7071	2.6 ± 1.9798
5.	*Cassia siamea*	0.866 ± 0.4147	1.07 ± 0.1164

Table 12. Level of total nitrogen in leaves of Control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	2.2089 ± 0.10129	1.4541 ± 0.2827
2.	*Dalbergia sissoo*	1.7205 ± 5.9624	1.6206 ± 0.6231
3.	*Azadirachta indica*	3.2079 ± 1.1582	18.7368 ± 9.8338
4.	*Ficus religiosa*	3.3966 ± 1.4127	12.7705 ± 15.5642
5.	*Cassia siamea*	10.6449 ± 9.7282	8.0808 ± 11.6909

Table 13. Level of total Phosphorus in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	1.4541 ± 0.7269	1.0298 ± 1.0298
2.	*Dalbergia sissoo*	1.6206 ± 5.6862	4.3414 ± 1.1477
3.	*Azadirachta indica*	18.7368 ± 88.9535	13.2701 ± 13.2701
4.	*Ficus religiosa*	12.7705 ± 0.4997	9.0446 ± 11.02336
5.	*Cassia siamea*	1.0927 ± 0.6837	5.7252 ±8.279861

Table 14. Level of total potassium in leaves of control (C) and polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	1.366 ± 0.3214	1.2 ± 0.3605
2.	*Dalbergia sissoo*	1.133 ± 1.2148	2.23 ± 0.5033
3.	*Azadirachta indica*	2.066 ± 0.5686	2.133 ± 0.4016
4.	*Ficus religiosa*	1.5 ± 0.1414	2.25 ± 0.7778
5.	*Cassia siamea*	1.4 ± 0.2645	1.4 ± 0.3872

Table 15. Level of total Na^+ in leaves of Control (C) and Polluted (P) samples

Sl. No.	Tree spp.	C (Mean ± S.D.)	P (Mean ± S.D.)
1.	*Pongamia pinnata*	0.09 ± 0.036	0.086 ± 0.0229
2.	*Dalbergia sissoo*	0.076 ± 0.065	0.076 ± 0.0206
3.	*Azadirachta indica*	0.09 ± 0.036	0.093 ± 0.0057
4.	*Ficus religiosa*	0.115 ± 0.49	0.095± 0.02121
5.	*Cassia siamea*	0.10 ±0.041	0.073 ± 0.0228

Table 16. Summary of automotive exhaust levels

Gases and particles	Gasoline exhaust	Diesel exhaust	Urban polluted air	Biological activity threshold	Air quality standards
Oxygen %	1-14	1-20	20.9	16-12	-
Nitrogen %	76-90		78.06	-	-
Hydrogen %	2-6	0.05-8		-	-
Carbon dioxide %	5-15	1-14	0.03-0.04	5	0.5
Carbon monoxide %	2-6	0-0.1	2-50 ppm	200-300 ppm	30-120 ppm
NOx ppm	30-4000	30-2000	0.001-0.15	-	3-10
NO_2 ppm	-	0.5-40	0.02-0.08	0.5-5	0.2-0.5
Photochemical oxidants ppm	-	-	-	0.13	0.015
Ozone ppm	-	-	0-0.2	0.1-0.5	
PAN ppm (peroxyacetyl nitrate)	-	-	0.01	0.1	0.03
SO_2 ppm	0-80	100-300	0.2-1.3	1-5	0.03-0.1
Total aldehydes ppm	40-300	10-120	0.2-1.2	0.06-0.1	-
Formaldehydes ppm	10-300	5-30	0.05- 0.12	0.5-16	-
Acrolein ppm	-	-	0.01	0.2-5	0.01
Total hydrocarbons	0.03-1.5%	0.01-0.10%	2-15 ppm	1-20 %	0.24 ppm
Methane ppm	200-800	-	1.0-1.5		1000
Benzopyrene	1-10 µg/ m^3	-	-	0.01-100 µg/ 1000 m^3	-
Lead	70-80% of the lead in gasoline	0	0.4-10 µg/m^3	-	15.50 µg/m^3
Oils mg/m^3		200-900		1200	
Particles	0.2-3 mg/g of burnt gasoline	150-450 mg/m^3	50-100 µg/m^3		60-75 µg/m^3
Cadmium µg/m^3	-	-	0.0004-0.26	200	-
Nickel µg/m^3	-	-	0.001-0.12	1000	-
Platinum µg/m^3	-	-		2	-

Source: Agarwal [1]

The level of organic carbon didn't show much difference between the polluted and control samples, and so was for available nitrogen. But the level of available potassium was found higher in the polluted samples of rhizospheric soil, which perfectly matches with the result of simulated acid-rain experiments at the TFRI nursery, cause of which is still to be investigated.

Levels of available phosphorous, exchangeable potassium, exchangeable sodium, and exchangeable calcium didn't show much difference between polluted and control samples, where the level of exchangeable calcium + magnesium was found significantly lower in the polluted samples then the normal one and that is at par with the normal trend of pollution reactions in the environment as reported by other workers.

From the above study, it is evident that in the summertime and in the soil composition of Jabalpur, India (where forests are tropical dry deciduous in nature), there seems existent and functional some unknown underlying mechanism which helps to bring the values of pH and cation exchange capacity of the rhizospheric soil of resistant tree species viz. *Pongamia pinnata, Dalbergia sissoo, Azadirachta indica, Ficus religiosa* and *Cassia siamea* towards normality.

This mechanism certainly helps in the absorption of nutrient molecules, and thus in the survival of the tree, and thus giving it the status of "resistant" in a totally adverse environment. The specific causes might be the physiological reactions in the roots, might be some root-associated reactions with microbe / micro-flora / micro-fauna, or something else, or an admixture of all these. Anyway, these findings put a milestone for an in-depth research in the important research area in present-day scenario of extreme urban roadside-pollution. It is already reported by many workers that in the polluted environment, the level of ascorbic acid gets reduced to a significant level, and surprisingly the phenomenon is parallel in the line of animal or human sickness, where the ascorbic acid level is found to get reduced in many cases. However, in our exhaustive study, it was found that this level was highest in case of *Azadirachta indica*, next for *Cassia siamea* in case of control samples. And interestingly, the level was found to be significantly high in case of *Cassia siamea*, when for all the other trees viz. *Pongamia pinnata, Dalbergia sissoo, Azadirachta indica, Ficus religiosa*, the levels were significantly low. This finding strongly indicates the suitability of *Cassia siamea* in the environmental region of Jabalpur, where the tree could develop resistance against the dreaded effects of air pollution emitted by the automotives, when the others showed physiological damage in terms of levels of ascorbic acid.

The level of total carbohydrate was found to be highest in *Dalbergia sissoo* in control area, when the same picture was reflected in the polluted samples. The increased level of carbohydrate generally reflects the damaged physiology of a tree, but in this case, as the level was found higher in both control and polluted, it may be inferred that this level is normal in case of *Dalbergia sissoo* in the environment of Jabalpur. However, the level was found to be lowest in *Pongamia pinnata* in the polluted samples, indicating its resistance and suitability in the region.

The level of phenol was found to be highest in case of *Cassia siamea* and lowest in *Ficus religiosa* in the polluted samples, where in the control samples the level was found highest in *Ficus religiosa*. This indicates damage caused by pollution in *Ficus religiosa*, and resistance offered by nature to *Cassia siamea*.

Magnesium metabolism is directly linked to the synthesis of chlorophyll molecule in plants. In the level of total magnesium in the leaves, it was found to be highest in case of *Cassia siamea* in both control and polluted samples, but the level was significantly lower in all other 4 species; this indicates that the automotive released air pollutants highly affects the metabolism of magnesium ions in the trees, which somehow *Cassia siamea* could counterbalance with some unknown physiological mechanism.

The metabolism and assimilation of calcium is very important in any living organism; total calcium was found to be highest in case of *Ficus religiosa* in both the control and polluted samples, indicating the resistance and suitability of the tree in the region; remarkably, this level was found much lower in all the other 4 species.

The level of total nitrogen indicates the synthesis of protein in an organism. This was found highest as a burst in case of *Azadirachta indica* and *Ficus religiosa* in the polluted samples, indicating the ability of the trees to generate the necessary resistant proteins to combat a polluted environment.

The level of total phosphorus indicates the synthesis of nucleic acids (DNA and RNA) in an organism; interestingly the level was found higher in both the cases of *Azadirachta indica* and *Ficus religiosa*, when for the other samples there found a trend of increase in the amount of phosphorus in the polluted area, which indicates that probably the formation of nucleic acids gets a boost due to the effect of air pollutants which might had switched on some gene expression to synthesize some proteins to combat the pollution effects. No significant difference was noticed in case of total sodium and total potassium between the control and the polluted samples, which is expected in terms of the nature of the soil and regional effects. In case of *Cassia siamea*, when magnesium is directly related to chlorophyll synthesis in plant body, it was noticed that in polluted area the level of total magnesium was significantly higher than the control sample; the chlorophyll level for both the samples were found almost at par, thereby indicating the physiological significance of the presence and accumulation of magnesium as a resistant feature for the plants existing in the polluted roadsides.

5. CONCLUSION

The above described data has provided an index-guideline for some reaction indicators and many important elements and compounds in pollution-resistant trees and their rhizospheric soils and has clearly demonstrated the probable sequences of end reactions of many a physiological events when the specified trees get exposed to dust and automotive air pollution in likely environment that of Jabalpur.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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