Environmental Pollution, A Threat to Photosynthesis in Healthy Plants

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Summary: Environmental pollutants, in atmosphere depend upon the source, strength, meteorological conditions and topography and effect the flora and fauna. Photosynthesis, which is the main necessity for plants to maintain their metabolic process, grow in size and for their reproduction, is directly or indirectly affected by manmade pollution. This synthetic pollution includes industrial discharge and vehicular exhaust, throws many toxic elements in air, water and soil in industrialized zone. To investigate this effect leave were collected from sunny, semi-shady and shady side of different trees at varying distance from industrial area and busy road and analyzed for various Photosynthetic pigments. The results show that average value of total chlorophyll varied in the range of 23-39mg/g, chlorophyll a, 5-19.6mg/g and b in the range of 5.6-20.3mg/g and carotene contents in the range of 17.6-41.3mg/g of the sample taken depending upon the type of the plant and the distance from industries and busy road. These values were in decreasing order of sunny > semi-shady > shady leaves. The concentration of all pigments increased as the distance from the industrial area and busy road increased. These values were comparatively lower as compared to the value in non-polluted areas. The soil and water samples from different sites around the trees in environmentally polluted and non polluted areas were also analyzed.

Introduction

Air is never found to be absolutely clean in nature. Pollution of air started from the very moment when the primitive man knew to make fire since then it has increased and still increasing every moment. Atmosphere that is air sector is continuous which diffuse and disperse the air pollutant at a greater rate with faster action. Air pollutants are substances causing damage to human beings, animals, plants, trees, buildings or material which is adversely affected by pollutants [1].

Major sources of air pollution are natural sources (volcanic eruption releasing poisonous gases like SO_2, H_2S, CO etc) and man-made sources like increase in population, deforestation, burning of fossil fuels and fire, emission from vehicles, rapid industrialization, agricultural activities and wars.

The vehicular exhaust, on the other hand, is responsible for more than 75% of total air pollution; a little detail of the issue is like cars, scooters, motors, taxies, truck etc release huge amount of poisonous gases such as CO (about 77%), NO (about 80%) and hydrocarbons (about 14%), in addition to loaded gases and particulate lead etc as a result of incomplete combustion of petrol and diesel which react with oxides of nitrogen in presence of sunlight to form photochemical smog in the atmosphere. This smog is very toxic in nature. The problem of vehicular air pollution is very complex because it is caused by a number of factors including outdated vehicular technology, poor fuel quality, poor maintenance and lack of traffic planning [2].

The other main source of man-made pollution is rapid industrialization. Chemical industries, paper and pulp mills, cotton mills, metallurgical plants and smelters, petroleum refineries, mining and synthetic rubber industries are responsible for about 20% of air pollution. The common pollutants of these industries are various types of inorganic and organic gases and particulates which are pumped in the air include CO_2, CO, SO_2, H_2S, NO, NO_2, small dust particles and even radioactive materials etc. All such gases and suspended particles are injurious to human health as well as plants [3, 4].

Plants play a vital role in creating healthy environment, however their life is at jeopardy as their growth rate is much affected by air pollution. The photosynthesis and the plant pigments formation is effected/ slow down due to traffic and industrial pollution. With the increase in volume of road traffic, the NO_x, VOCs and the particulates deposition increases causing uncertain effects on roadside

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plants. Gaseous pollutants enter the plants through stomata in the leaves, over the cuticle or epicuticular wax covering and damage them. The particulate from vehicular exhaust affect these epicuticular waxes and hence reduce cuticular resistance to gas diffusion and effect stomata responses. On the other hand unplanned industrialization deteriorates the surface and water quality due to addition of used water having constituents of undesirable concentration. It has been observed that effluents from many industries are either transferred to canal or river through a surface drain or allowed to spread near agricultural fields. These effluents are used as a source of irrigation when there is shortage of water [5-11].

The vegetation surfaces act as a platform for pollutants and parasites interaction. Thus due to the effluents, the root hairs and stomata do not perform their work properly. Exposure of pollutants in combination may be more harmful to plants than individual ones [12]. Several researchers have evidence which indicate that stomata densities change in response to changing Environment [13, 14].

On the other hand the higher trees are the sites of a variety of air borne biological material and atmospheric pollutants [15]. The pollutant may also change the morphology, physiology and biochemistry of sensitive plants. Chronic exposure of SO_2 to plants causes bleaching of leaf pigments, due to conversion of chlorophyll a to phacophytin reducing plant productivity [16]. High concentration of NO_2 inhibits photosynthesis causing silvering of leaves. Drying of leaves occur more quickly in plants at the road-side, suggesting some loss of drought tolerance in these plants.

Heavy metals present in ground water or leach to earth surface by rainwater, absorbed by the plants through roots and ultimately reach to the leaves of the plants through routine transpiration within the plant body. Heavy metal may also be absorbed directly from the air. A decrease in total chlorophyll contents with metal toxicity has been observed in plants. Heavy metals block the synthesis of activity of enzyme amino-levulinic acid dehydralase (ALAD) responsible for chlorophyll biogenesis. It has been noted that Cd is present in tires up to the concentration of 20-90ppm. This Cd is thrown in to the air and absorbed by the plants which decrease the leaf chlorophyll.

Since effect of pollutants on plants is manifested on their leaves, leaf of the plants can be considered as index of pollution. The present study was therefore carried out to investigate the effect of toxic components emitted by vehicles or industries that is man-made pollution on pigments formation and photosynthesis process of plants and to correlate them with the extent of pollution in that area.[17-19].

To observe the effect of traffic and industrial pollution on the photosynthesis of plants, different samples of leaves of plants were taken from different sites around the chashma sugar mill and National woolen mill along 24 hours busy road and analyzed for total chlorophyll, chlorophyll a, chlorophyll b and carotene content. Beside this the lead in the roadside soil and plant samples was also determined.

Air pollutants at various distances from busy University road, were also determined. The experimental study was also conducted on leaves of plants far from polluted area (For comparison). Water and soil samples were also analyzed for Industrial area and Non-industrial area.

Results and Discussion

The data Tables 1-3 shows the various parameters which were obtained by analysis of leaves after homogenization. The data shows that mean value of photosynthetic pigments varies with the distance of plants from the road that is increases as the distance of plants from road increases. Further information which the Tables 1-3 show is that individual value of all the pigments that is total chlorophyll, chlorophyll a, chlorophyll b and carotene contents decreases in order of sunny, semi-shady and shady leaves indicating the importance of light for the pigment formation.

The comparison of photosynthetic pigments in industrial and non-industrial area is shown in Table-7. The Table-4 shows the results of analyses of road side soil of the same location from which the plant samples were collected. The analyses show that the samples which were collected near the road side have more lead as compared to those collected away from road. This change in lead level in samples is due to high traffic density in that area which is the major cause of pollution.

Table-8 and Table-9 shows the analysis data of water and soil in industrial area (near the road) and

Table-1: Analysis of Photosynthetic Pigments in Sunny, Semi shady and shady leaves of Guava tree at various distances from busy road.

Distance from the Road	Leaves	Total Chl (mg/g)	Mean	Chl-a (mg/g)	Mean	Chl-b (mg/g)	Mean	Carotene (mg/g)	Mean
30m	Sunny	26	24	15	13.6	13	11.6	21	17.6
	Semishady	23		13		11		19	
	Shady	23		13		11		13	
180m	Sunny	29	26.3	17	15	15	13	25	21
	Semishady	25		15		13		21	
	Shady	25		13		11		17	
320m	Sunny	31	28.3	19	17.6	17	16.3	31	25
	Semishady	27		17		17		25	
	Shady	27		17		15		19	

Table-2: Analysis of Photosynthetic Pigments in Sunny, Semishady and shady leaves of Orange tree at various distances from busy road.

Distance from the Road	Leaves	Total Chl (mg/g)	Mean	Chl-a (mg/g)	Mean	Chl-b (mg/g)	Mean	Carotene (mg/g)	Mean
210m	Sunny	33	31	19	17.6	19	17	27	23
	Semishady	31		17		17		23	
	Shady	29		17		15		19	
520m	Sunny	37	34.3	19	19	21	19	35	27.6
	Semishady	33		19		19		27	
	Shady	33		19		17		21	
700m	Sunny	39	36.3	21	19.6	21	20.3	31	29
	Semishady	37		19		21		29	
	Shady	33		19		19		27	

Table-3: Analysis of Photosynthetic Pigments in Sunny, Semishady and shady leaves of Apricot tree at various distances from busy road.

Distance from the Road	Leaves	Total Chl (mg/g)	Mean	Chl-a (mg/g)	Mean	Chl-b (mg/g)	Mean	Carotene (mg/g)	Mean
25m	Sunny	13	11.3	07	5.6	07	5.6	35	32
	Semishady	11		05		05		32	
	Shady	10		05		05		29	
200m	Sunny	15	12.6	09	7	10	7.3	39	36.3
	Semishady	13		07		07		35	
	Shady	10		05		05		33	
400m	Sunny	21	20	11	9	13	11.6	43	41.3
	Semishady	21		09		11		42	
	Shady	18		07		11		39	

Table-4: Lead contamination of Roadside soil and Plants.

Distance from University Road (m)	Lead in washed leaf sample (ug/g)	Lead in soil sample (ug/g)
10	560	610
50	445	500
100	300	385
200	280	295
500	150	180

Table-5: Air pollutants at various distances from Road.

Location	Particulates (mg/m^3)	NO2 (mg/m^3)	SO2 (mg/m^3)	CO (mg/m^3)
At 10m from the Road	0.53	0.25	2.10	20.01
At 50m from the Road	0.38	0.19	1.48	19.02
At 100m from the Road	0.17	0.14	1.01	17.1
At 200m from the Road	0.10	0.1	0.85	12.5
At 500m from the Road	0.07	0.08	0.61	8.6
At 700m from the Road	.05	0.04	0.30	5.4

Table-6: National Air quality standards (NAQS) for gaseous pollutants.

Pollutants	Time Span	U.S Standards	W.H.O Standards
SO2	1 hour 24 hour	$365ug/m^3$	$350ug/m^3$
NO2	24 hour Annual	$100ug/m^3$	$150ug/m^3$
CO	1 hr 8 hr	$40mg/m^3$ $10mg/m^3$	$30mg/m^3$ $10mg/m^3$

non-industrial area (away from road). The Table-8 and Table-9 show that the hardness of soil and underground water in the non-industrial area is in the range of 8-12mg/l and 16-20mg/l respectively which is normal because of no effect of industrial effluents whereas the hardness of soil and underground water in the industrial area is comparatively high in the range of 26-43mg/l and 34-37mg/l respectively due to seepage of industrial effluents and traffic pollution.

The pH of ground water samples is in the range of 7.4-7.6 in non-industrial area and is 7.5-7.8 in the industrial area. The pH and the hardness fall

Table-7: Analysis of Photosynthetic Pigments in the leaves of orange tree in non- industrial area (NA) and industrial area (I.A).

Leaves of Orange tree	Total Chlorophyll (mg/g)		Chlorophyll-a (mg/g)		Chlorophyll-b (mg/g)		Carotene contents (mg/g)	
	Non-industrial area	Industrial area	Non-industrial area	Industrial area	Non-industrial area	Industrial area	Non-industrial area	Industrial area
Sunny	41	36	25	20	25	18	36	36
Semishady	32	27	20	14	20	17	24	24
Shady	27	23	17	12	17	16	16	16

Table-8: Analysis of water samples taken near the Orange trees in Non- industrial (NA) area and Industrial area (IA).

No.	pH		EC (ms)		Hardness (mg/l)		Total Alkalinity (ppm)		Turbidity (ppm)		Na (ppm)		K (ppm)		Lead (ppm)		Cl (mg/l)		SO4 (mg/l)	
	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA
1	7.4	7.5	3.4	3.1	17	34	302	463	29	42	4.4	5.2	2.1	1.8	0.05	0.06	325	350	201	251
2	7.5	7.7	3.1	4.0	20	35	361	405	26	41	4.5	6.1	2.0	2.6	0.04	0.05	360	427	208	240
3	7.5	7.8	3.2	4.3	16	37	384	448	38	39	2.9	5.3	1.6	2.1	0.04	0.05	356	450	216	260

Table-9: Analysis of soil samples taken near the Orange trees in Non- industrial (NA) area and Industrial area (IA).

No.	pH		EC (ms)		Hardness (mg/l)		Total Alkalinity (ppm)		Turbidity (ppm)		Na (ppm)		K (ppm)		Lead (ppm)		Cl (mg/l)		SO4 (mg/l)	
	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA	NA	IA
1	7.0	8.4	7.0	7.4	12	26	22	32	26	70	4.3	4.8	2.2	2.5	0.02	0.05	412	448	210	236
2	7.4	8.0	7.4	7.6	08	37	27	31	37	74	4.5	4.2	3.9	4.2	0.01	0.02	350	461	224	281
3	7.2	7.8	7.2	7.8	12	43	27	31	40	71	4.2	7.8	2.4	3.0	0.02	0.04	250	421	229	254

within the permissible limits recommended by NEQS [20]. Other parameter electric conductivity EC, Cl^-, SO^{-4}, Pb^{+2}etc are presented in Table-8 and Table-9.

The entire constituents in the water and soil samples of industrial area are higher as compared to those of non-industrial area. However the quality of the water and soil was found to be satisfactory that is within the permissible limits.

The air samples of the roadside and around the trees under study were collected and analyzed to deduce the effect of traffic pollution over the environment. The air analysis shows that the concentration of lead, CO, SO_2 and NO (Table-5) were comparatively high in the dense traffic area and decreased as we move away from the busy road. These finding are in agreement with the work reported earlier [21-26]. Table- 6 shows the National Air Quality Standards (NAQS) for gaseous pollutants.

Based on air, soil and water analysis it seems that the vehicular emission and industrial effluents are the major sources of threat over the process of photosynthesis because they directly effect the leaf surface area which is considered as an index of photosynthetic biomass but the physical and chemical characteristics of leaf can vary significantly even on a single plant depending on age and environmental variables.

Experimental

Reagents

All chemicals were of reagent grade and obtained from either B.D.H England or E. Merck Germany. All the solvents were distilled before use. Double distilled water was used for preparation of solutions.

Instruments

The instruments used were spectronic-21 (Bausch and Lamb Japan), Atomic absorption spectrophotometer (AA-202, Brukar USA), High volume dust apparatus (NILFISK, GS80, Finland), General purpose gas analyzer (Foxboro, USA), Conductometer (Jenway, 4010), pH meter (corning-EEL, model 12) and Flame photometer (Corning 410, UK).

Sample Collection

Samples of leaves from different trees of Dera Ismail Khan were collected. The trees were selected in such a way that they were at 10 to 700m from the main university road near sugar mill and woolen mill. The samples after plucking were stored in air container and labeled before bringing them to the laboratory. The samples were collected from available trees on the basis of assuming them active air pollutant absorbing site.

For water and soil analysis the samples were collected in the vicinity of trees under study. Water samples were collected in clean polyethylene bottles.

Procedure

All the leaves samples were well washed with water till the removal of dust and smoke from the surface and dried at 110°C up to constant weight.

One gram of dried sample of the leaves in each case was homogenized in 5 ml distilled water in a blender. The final volume was made up to 100ml with same water. An aliquot of 0.5 ml was taken and mixed with 4.5 ml of 80% acetone. The mixture was centrifuged and the supernatant was used for determination of total chlorophyll, chlorophyll a, chlorophyll b and the carotene content by measuring optical density at their respective wavelengths.

Water and soil samples were analyzed by adopting standard techniques [21, 27, 28] to avoid significant changes in their composition before analysis. Hardness, alkalinity and the chloride ions were determined by Voltametric methods of analysis. Sulphate ions were determined using gravimetric methods of analysis. pH was determined using pH meter and conductivity was measured by conductometer. Na and K+ were analyzed with the help of flame photometer.

For lead analysis one gram of washed leaves in each case was burnt to ash at 650°C. The ash was dissolved in 5ml of mixture of HCl and HNO_3 (5:1). The mixture was filtered and the residue ash was washed till free of acids. The washings and filtrate were combined and evaporated to a constant volume of 50ml which was then analyzed for lead by atomic absorption spectrophotometer. The soil samples were also treated in the same way and all analyses were performed in triplicate.

Air samples were collected at various distances from road near the investigating trees using high volume dust apparatus (NILFISK, type GS 80, Finland). CO, SO_2 and NO_2 in the air samples were analyzed using general purpose gas analyzer (FOXBORO, USA). All the experimental results were compared with the US and W.H.O standards [19].

Conclusions

The above studies show that industrial emission (and waste) and vehicular emission have harmful effects on the pigments concentration contained in chloroplast which is the main requirement for the photosynthesis and in turn necessary for growth of plants .When these effluents (either come through smoke or through roots in to the interior of plant) settles on plants, they limit photosynthesis by cutting out light and limit transpiration by blocking stomata.

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