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Assessment of Air Pollution Using Plant Chlorophyll Concentration Reduction Criterion in Benin City, Edo State

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ABSTRACT: Air pollution assessment was carried out using chlorophyll concentration reduction criterion of some higher plants leaves such as (Masquerade tree) *Polyathia longifolia* (Sonn.) Thwaites, (Mango) *Mangifera indica* Linn. (Guava) *Psidium guajava* Linn. and (Indian Almond) *Terminalia catappa* Linn. as the bio-indicator species. The study was carried out at three (3) different locations namely polluted area (Ring Road, Benin City), slightly polluted area (Ekosodin Gate) and unpolluted area (Professor's Staff Quarters) inside University of Benin, Ugbowo Campus, Benin City, Edo State, Nigeria. Chlorophyll content of intact matured leaves of study plants were measured *in situ* using a hand-held digital chlorophyll content meter CCM 200 Plus. The study revealed that there were significant reduction ($P < 0.05$) of chlorophyll concentration at Ring Road area and Ekosodin Gate area when compared with plants at Professors' Quarters. The percentage chlorophyll reduction at Ring Road and Ekosodin Gate in *Polyathia longifolia*, *Mangifera indica*, *Psidium guajava*, and *Terminalia catappa* leaves in relation to the Professors' Quarters were 46.63 %, 45.08 %, 45.03 %, 31.79 % and 23.85 %, 25.46 %, 23.94 %, 25.71 % respectively. These results confirmed that Ring Road is highly polluted than the other study areas. This study revealed that changes occurred in chlorophyll content of plants due to air pollution and that plant act as a sink for air pollutant which deteriorates their photosynthetic pigments which invariably leads to reduction in plant productivity. This study, therefore shows that plants chlorophyll content can be used as bio-indicator of pollution.

Keywords: Air pollution, Higher plants, Chlorophyll concentration, Bio-indicator

Introduction

Man's desire to satisfy his want has resulted in environmental degradation and depletion of resources. This may have resulted from the exploration of resources, thus making the pollution of ecosystem deliberately or inadvertently a fact of life. Our usual pristine earth is gradually becoming history and is being taken over by myriad of hazards whose consequence are at times difficult to fully comprehend (Adenipekun *et al.*, 2008).

Urban air pollution is a serious problem in both developing and developed countries (Li, 2003). Air pollutants, responsible for vegetation injury and crop yield losses, are of increasing concern (Joshi and Swami, 2007). The increasing number of industries and automobile vehicles are continuously adding toxic gases and other substances to the environment (Jahan and Iqbal, 1992). All combustion release gases and particles into the air. These include sulphur and nitrogen oxides, carbon monoxide and soot particles, as well as smaller quantities of toxic metals, organic molecules and radioactive isotope (Agbaire and Esiefarienrhe, 2009).

According to Bamidele and Agbogidi (2000), pollution can be defined as the introduction of contaminant into an environment that causes instability, disorder, harm and discomfort to the ecosystem. It could be in the form of chemical substances or energy. The Federal Environmental Protection Agency (FEPA, 1992) defines pollution as man-made or man-aided alteration of chemical, physical or biological quality of the environment to the extent that is detrimental to that environment or beyond acceptable limits. De Jong (1980) defines it as the release of

substances or energy into the environment by man in quantities that damages either the earth or resources. Pollution can also be defined as an addition by nature (for example volcanic eruptions) or by man (oil spillage), to air, water or soil that threatens the health, survival activities of humans and other living organism (Odukuma and Dickson, 2003).

Air pollution, on the other hand, refers to any atmospheric condition in which certain substances are present in such concentrations that they produce undesirable effects on man and his environment (Admassu and Wubeshet, 2006). Air pollution has a drastic impact on living and non-living components of the ecosystem because air is an important and vital component of earth's environment and any slight change in its composition can have varied effects on the growth, development and survival of different organism on the planet (Mir *et al.*, 2008).

The distribution of plant diversity is highly dependent on the presence of air pollutants in the ambient air and the sensitivity of the plants. Chlorophyll measurement is an important tool to evaluate the effects of air pollutants on plants as it plays an important role in plant metabolism and any reduction in chlorophyll content corresponds directly to plant growth (Joshi and Swami, 2009). Chlorophyll is an index of productivity of plant. Vegetation is an effective indicator of the overall impact of air pollution, and the effect observed is a time-averaged result that is more reliable than the one obtained from direct determination of the pollutant in air over a short period (Seyyednejad and Koochak, 2013).

Urban pollution has become a serious environmental problem to trees and crops (Chauhan and Joshi, 2008). In many urban areas of the world, motor vehicle traffic is a major source of air pollution contributing 57 – 75 % of total emission (WHO, 2006). The largest contributors to urban outdoor air pollution in both developed and developing countries are motorized transportation, small-scale manufacturers and other industries, burning of biomass and coal for cooking and heating and coal -fired power plants (WHO, 2006). Roadside growing plants are more affected by air pollutants because of heavy traffic load. In polluted area plants show several changes in morphology, physiology, anatomy, and biochemistry of leaves. Leaves are sensitive parts of the plant because of the abundance of stomata on the surface, from which pollutants penetrate into the sensitive tissues of leaves. Plants act as sink for pollutants (Pahak *et al.*, 2015). Air pollutants from motor vehicle exhausts have both direct and indirect effects on the metabolism of roadside plants even before visible symptoms appear (Viskari *et al.*, 2000). Polluted air may have profound effect on the growth and development of vegetation. Trees by virtue of their perennial habit, experience the greatest exposure and are greatly influenced by any appreciable change in the environment (Raina and Sharma, 2003).

The exposure of pollutants to leaves cause a reduction in the concentration of their photosynthetic pigments viz., chlorophyll and carotenoids, which affects the plants productivity, germination of seeds, length of pedicels, and number of flowers or inflorescence. Air pollution can directly affect plants via leaves or indirectly via soil acidification. When exposed to airborne pollutants, most plants experienced physiological changes before exhibiting visible damage to leaves (Liu and Ding, 2008). Air pollution stress leads to stomatal closure, which reduces CO_2 availability in leaves and inhibits carbon fixation. Net photosynthetic rate is a commonly used indicator of impact of increased air pollutants on tree growth (Woo *et al.*, 2007). Industrialization and the automobiles are responsible for maximum amount of air pollutants and the crop plants are very sensitive to gaseous and particulate pollution and these can be used as indicators of air pollution (Joshi *et al.*, 2009).

The present knowledge of the effects of air pollution on plants is mostly based on experiments, where plants have been exposed to high concentrations of air pollutants for short periods under experimental conditions. However, less is known about the responses of plants to air pollutants at environmentally relevant concentrations and for long durations under field conditions (Li, 2003).

The present study was, therefore, carried out to determine the effect of air pollutant on the chlorophyll pigment of some roadside trees.

Materials and methods

Study area: The study was carried out at three (3) different areas in Benin City, Edo State, Nigeria, which were termed: highly polluted, slightly polluted and unpolluted due to the volume of vehicular movement in the area. Benin City, the capital of Edo State, is located in the South-South geopolitical region of Nigeria. It is bounded by latitude 06° 11″ N, 06° 27″ N (Southern and Northern boundaries) and longitude 005° 31″ E and 005° 44″ E (Western and Eastern boundaries). It has an estimated land area of 500 km^2 (Erah *et al.*, 2002) and 3,218,332 population (National Bureau of Statistics, 2009). The City falls within the tropical equatorial zone characterized by dry and wet seasons, with an estimated annual rainfall of over 2000 mm and an average temperature of 27 °C (Omofonmwan and Eseigbe, 2009). The wet season spans between the months of March and October, while the shorter dry season begins in November and ends in February. Generally, rain falls all year round in Benin City with double peak periods in the month of June or July and September, and a short temporal break in August

(National Bureau of Statistics, 2009). It comprises four local government areas namely Ikpoba Okha, Oredo, Ovia North East and Egor.

One of the locations is at Ring Road (a commercial area) in Oredo local government area, Benin City, Edo State, Southern Nigeria at Latitude 06° 20′ 05.1″ N and Longitude 005° 37′ 17.0″ E at 90 m elevation above sea level. This place was termed polluted because lots of vehicles ply the Ring Road area, there is very high vehicular emission and this seriously affects plants in this area. This area is the commercial nerve centre of Benin City where a major market the Oba market is located. It is categorized as commercial land use which include trading stores and outlets, transportation hubs and distribution centres of goods and services. Also, it is a central business district (Balogun and Orimoogunje, 2015).

The second area of study was at Ekosodin Gate, situated inside the University of Benin (an institutional area) in Ovia North East local government area of Benin City. It is bounded by Latitude N 06° 24′ 18.7″ and Longitude 005° 37′ 17.8″ E at 104 m elevation above sea level. This area was termed slightly polluted because, the number of vehicles plying this area is moderate and not as high as in Ring Road area. The third area was Professors' Staff Quarters where some of the professors and senior academic and non-academic staff resides inside the University of Benin, Ugbowo Campus (an institutional area). It is bounded by Latitude 06° 24′ 16.3″ N and Longitude 005° 36′ 52.8″ E; at 139 m elevation above sea level. Vehicular emission is drastically reduced because of lesser vehicular movements in this area as compared with the other two locations and as such, this area was termed unpolluted and was used as the control site.

Experimental protocol: The chlorophyll contents of the leaves of the study plants were determined using Chlorophyll meter CCM 200 Plus (Apogee Instrument, USA). The plants selected for the study were common to the three locations. For each location, chlorophyll measurement was carried out on three (3) stands of each of the experimental plants. The chlorophyll contents of thirty (30) randomly selected leaves from each experimental plant were determined *in situ* for the three (3) locations with the digital equipment without detachment by placing each leaf between the arm of the equipment and pressing it on the leaf to take the reading. The CCM- 200 plus uses absorbance to estimate the relative chlorophyll content in leaf tissue. Two wavelengths are used for absorbance determinations. One wavelength falls within the chlorophyll absorbance range while the other serves to compensate mechanical differences such as tissue thickness. The meter measures the absorbance range of both wavelengths and calculates a Chlorophyll Concentration Index (CCI) which is proportional to the amount of chlorophyll in the sample (Apogee, 2021):

$$\text{CCI} = \frac{\text{\% Transmission at 931 nm}}{\text{\% Transmission at 653 nm}}$$

Results

The results of the chlorophyll concentrations of the studied trees are shown in Figures 1 to 4, while the percentage chlorophyll concentration reduction is shown in Table 1.

There were significant differences in chlorophyll concentration index ($P < 0.05$) of all trees in the three studied areas except for *Terminalia catappa* in which no significant difference ($P > 0.05$) was observed both at Ring Road (Polluted Area) and Ekosodin Gate (Slightly Polluted Area) Figure 4.

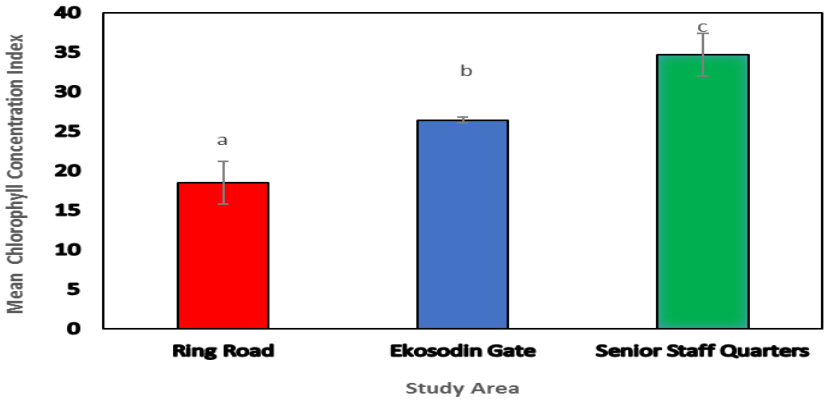

Figure 1: Variation in Chlorophyll Concentration Index of *Polyathia longifolia* at Ring Road, Ekosodin Gate and Senior Staff Quarters of University of Benin, Benin City

*Bars with different alphabets are significantly different from each other ($P < 0.05$)

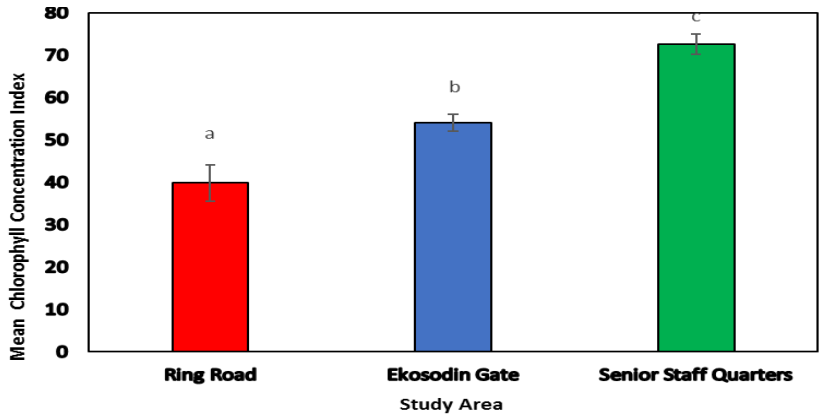

Figure 2: Variation in Chlorophyll Concentration Index of *Mangifera indica* at Ring Road, Ekosodin Gate and Senior Staff Quarters of University of Benin, Benin City.
*Bars with different alphabets are significantly different from each other ($P < 0.05$)

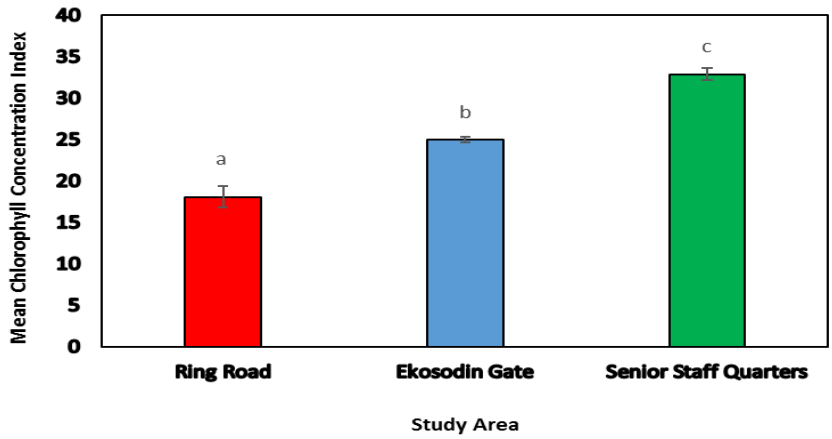

Figure 3: Variation in Chlorophyll Concentration Index of *Psidium guajava* at Ring Road, Ekosodin Gate and Senior Staff Quarters of University of Benin, Benin City.
*Bars with different alphabets are significantly different from each other ($P < 0.05$)

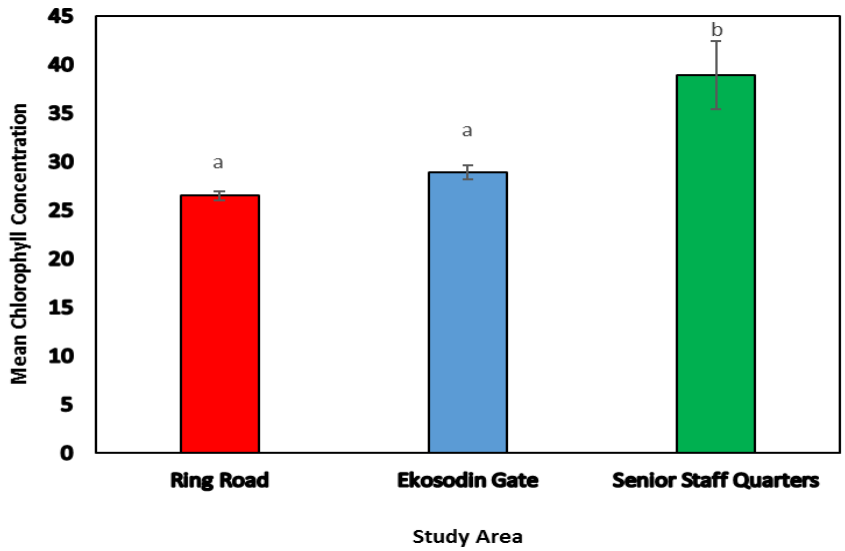

Figure 4: Variation in Chlorophyll Concentration Index of *Terminalia catappa* at Ring Road, Ekosodin Gate and Senior Staff Quarters of University of Benin, Benin City
*Bars with similar alphabets are not significantly different from each other ($P > 0.05$)

Table 1: Chlorophyll concentration index and percentage reduction at polluted and slightly polluted study areas in Benin City, Edo State.

Study Plant	Ring Road		Ekosodin Gate	
	Chlorophyll Conc. Index ± SEM	**% Chlorophyll Conc. Index Reduction**	**Chlorophyll Conc. Index ± SEM**	**% Chlorophyll Conc. Index Reduction**
Polyalthia longifolia	18.50 ± 2.69	46.63 %	26.40 ± 0.36	23.85 %
Mangifera indica	39.83 ± 4.33	45.08 %	54.07 ± 2.00	25.46 %
Psidium guajava	18.07 ± 1.26	45.03 %	25.00 ± 0.33	23.94 %
Terminalia catappa	26.53 ± 0.47	31.79 %	28.90 ± 0.75	25.71 %

SEM = Standard error of mean

Discussion

The result of this experiment demonstrated the adverse effects of air pollution on plants. It also revealed that exposure of plants to air pollutants caused a reduction in their leaf chlorophyll concentration, which affected plant productivity. The chlorophyll is a pigment that plants cannot do without, as it is the major photosynthetic element in plants. Moreover, it is the principal photoreceptor in photosynthesis, light-driven process by which carbon dioxide is "fixed" to yield carbohydrates and oxygen (Giri *et al.*, 2013).

In this study, it was shown that air pollution had significant effect on chlorophyll content of *Polyalthia longifolia* in the highly polluted area (Ring Road) and slightly polluted area (Ekosodin Gate) as compared with non-polluted area. This is in agreement with Adedipe *et al.*, 1973 and Pleijel *et al.*, 1994 who reported decrease in chlorophyll content of leaves of *Nicotiana tabacum* and *Avena sativa* following exposure to ozone. The reduction in chlorophyll content of *P. longifolia* in the polluted study areas (Ring Road and Ekosodin Gate) indicated that chlorophyll reduction is generally attributed to air pollution, caused by the constant release of automobile exhaust and dust in mentioned areas. This finding is in agreement with those of Leghari *et al.* (2013) who reported that where there is high vehicular emission, heavy metals released from automobile are extremely toxic and reduce plant growth and morphological parameters. This result is also in line with those of Seyyednejad and Koochak (2013) who reported decrease in total chlorophyll content of *Prosopis juliflora* leaves at polluted site. Pollutants when absorbed by leaves, may cause a reduction in the concentration of photosynthetic pigments viz., chlorophyll and carotenoids, which directly affect plant productivity (Joshi and Swami, 2009). Mills (2009) reported that physiological damage caused by air pollutants includes reduction in photosynthesis and reproductive potential.

The air we breathe is an essential ingredient for our wellbeing and a healthy life (Khanand Ghouri, 2011). Unfortunately, polluted air is common throughout the world (EPHA, 2009). It contains one, or more, hazardous substance, pollutant, or contaminant that creates a hazard to general health (Health and Energy, 2007). The main pollutants in the air we breathe include, particulate matter, PAHs, lead, ground-level ozone, heavy metals, Sulphur dioxide, benzene, carbon monoxide and Nitrogen dioxide (EPHA, 2009). Air pollution is the cause of ill health and death by natural and man-made sources. The total chlorophyll content of *M. indica* decreased significantly in response to air pollutants in the highly polluted area (Ring Road) and slightly polluted area (Ekosodin Gate). This result is comparable to the finding of Iqbal *et al.* (2015) who reported a high total chlorophyll concentrations of *Azadirachta indica, Conocarpus erectus, Guiacum officinale and Eucalyptus* sp. in control site as compared with the polluted area of the city. Air pollutants have been shown to reduce the synthesis of chlorophyll and enhance degradation of chlorophyll (Sandelius *et al.*, 1995). The results in this research is in agreement with the research of Chauhan (2010) who reported a decrease in the chlorophyll content of *Ficus religiosa, M. indica, P. longifolia* and *Delonix regia* at polluted site in Dehradun City in India as compared with the control site.

A significant reduction of the total chlorophyll content of *Psidium guajava* was observed at Ring Road and Ekosodin Gate areas as compared with Professors' Staff Quarters, this can be attributed to the air pollution at the two locations. This result is in line with those of Chaurasia *et al.* (2013) who reported the presence of more chlorophyll concentration in *Arachis hypogaea, Sesamum indicum* and *Triticum* sp. that were far away from cement factory and compared with those near to the industry. Also, this result is an agreement with the finding of Giri *et al.* (2013) who reported a significant reduction in chlorophyll content of *A. indica, Nerium oleander, M. indica* and *Dalbergia sissoo* due to air pollution.

Furthermore, air pollution also had significant effect on chlorophyll content of *T. catappa* at highly polluted area (Ring Road) and slightly polluted area (Ekosodin Gate) as compared with non- polluted area (Professors' Staff Quarters). The reduction in chlorophyll content of *T. catappa* in the polluted study area (Ring Road and Ekosodin Gate) could be attributed to the air pollution caused by the constant release of gases, fumes and smoke from automobile exhaust and dust in those areas. This result is similar to that of Chauhan and Joshi (2010) who reported that the chlorophyll content of wheat and mustard plants decreased significantly in response to air pollutants in highly polluted site. Similarly, Pathak *et al.* (2015) recorded reduction in chlorophyll content in the leaves of *Bouganvillea spectabilis* and *Dalbergia sissoo* at polluted site and attributed the reduction to emission of SO_2 and NO_2 and other gases in the air.

Air pollution in cities causes a shorter lifespan for city dwellers (Progressive Insurance, 2005). Particulate and related air pollutants at high levels pose hazards to human health (Holland *et al.*, 1979). The rapid growth in urban population, increasing industrialization, and rising demands for energy and motor vehicles are worsening air pollution levels (Mishra, 2003). Nigeria and most developing countries are also susceptible to the impact of industrialization and increasing commercial activities on the quality of air especially within urban centres (Balogun and Orimoogunje, 2015). Airborne particulates are the most obvious form of pollution in most Nigerian cities (Ukpebor *et al.*, 2006). Leafy vegetation along an unpaved highway may witness poor growth due to excessive amounts of settled dust which block stomata, damage tissue and retard photosynthesis. Dust is the primary particulate pollutant of many atmospheres and serves as a nucleation centre, which can reduce precipitation (Horsefall and Spiff, 2013).

Air pollution results in cancer (Ries *et al.*, 1999; EPHA, 2009), neuro-behavioural disorders (Mendola *et al.*, 2002; Blaxill, 2004), asthma (Gehring *et al.*, 2002; Brauer *et al.*, 2007), asthma exacerbations (Heinrich and Wichmann, 2004; D'Amato *et al.*, 2005, Nel, 2005), headaches and dizziness, irritation of eyes, nose, mouth and throat (Colls, 2002), reduced lung functioning (Colls, 2002; Gauderman *et al.*, 2005), respiratory symptoms (Vichit-Vadakan, 2001; Colls, 2002), respiratory disease (EPHA, 2009), disruption of endocrine (Crisp *et al.*, 1998; Colls, 2002, EPA, 2009) and reproductive and immune systems (Colls, 2002, EPHA, 2009), and premature death (EPHA, 2009).

Conclusion

In this study, it was shown that changes occurred in chlorophyll content of plants due to air pollution. This implies that in the presence of air pollutants, plant productivity are bound to reduce. It also showed that plant act as a sink for air pollutant which deteriorates their photosynthetic pigments. Therefore, this study can be used as bio-indicator tool for determining a polluted area due to air pollutants. Air pollution causes lots of damage to plants and animals including humans and as such, measures should be taken to reduce the amount of pollutants released into the atmosphere, knowing that anything that affects plants can directly or indirectly affect man.

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