Effects of dumpsites air pollution on the ascorbic acid and chlorophyll contents of medicinal plants

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Abstract: Deposition of air pollutants emitted from municipal solid waste on the leaves of plants growing within the vicinity of dumpsites has adverse effects on their morphological, physiological, and biochemical properties. In this study, the effects of air pollutants on the ascorbic acid and chlorophyll contents of Chromolaena odorata and Morinda lucida collected from Aba-Eku, Ajakanga, Awotan, and Lapite dumpsites, Ibadan, Nigeria, were investigated. Leaves of each plant species were separately collected and extracted with different reagents; thereafter, the ascorbic acid and chlorophyll contents of the aliquots were measured using UV/Visible spectrophotometry. Significant reductions of 13.90–61.00%; 13.85–60.43%; 13.88–60.75%; and 12.23–28.29%, respectively, occurred in the chlorophyll A, chlorophyll B, total chlorophyll, and ascorbic acid contents of the two plant species collected from the four dumpsites in comparison to the control site. The decreasing order of the percentage reduction in the ascorbic acid and chlorophyll contents of the two plant species collected at the four dumpsites is Ajakanga > Aba-Eku > Lapite > Awotan. Negative correlations revealed that reductions in chlorophyll and ascorbic acid contents of the two plant species could be attributed to deposition of air pollutants emitted from the municipal solid waste on the plants’ tissues.

ABOUT THE AUTHORS

Bamidele Ayodeji Falusi is actively involved in research activities on environmental issues. He has a number of international journal articles on determination of contents of heavy, toxic and trace metals in soils, plant and animal tissues. Omobola Ajibike Odedokun and Adiketu Abubakar have special interest in Chemistry education researches. They have individually and jointly published several journal articles on different issues involving Chemistry education in schools in Nigeria.

Bamidele Ayodeji Falusi, Adiketu Abubakar, and Augustina Agoh as a research group, have carried out a number of studies involving accumulation of trace and toxic elements by biota in different ecosystems. The current work provides an insight into the adverse effect of air pollution on biological tissues which are exposed daily to various kinds of pollutants at polluted sites. Augustina Agoh is specially interested in Biology education researches. She has published several journal articles on different issues in Biology education in Nigerian schools.

PUBLIC INTEREST STATEMENT

Chromolaena odorata and Morinda lucida have many reported medicinal values. However, exposure of plants to air pollution has resulted in significant reduction in many properties of such plants. Municipal solid wastes are associated with the emission of a number of air pollutants whose deposition on the leaves of plants growing within the vicinity of dumpsites could cause significant adverse effects to such plants. Exposure of C. odorata and M. lucida to air pollutants at the four government approved dumpsites in Ibadan, Nigeria, revealed significant reduction in their ascorbic acid and chlorophyll contents in comparison to unpolluted control site.
1. Introduction

Pollution is mainly caused by human activities like dumping of waste products, incomplete combustion of fossil fuels, burning of firewood, or other harmful secondary products which are harmful to living organisms (Lohe et al., 2015; Tripathi & Gautam, 2007). All combustion releases gasses and particles into the air. These can include sulfur and nitrogen oxides, carbon monoxide, and soot particles, as well as smaller quantities of toxic metals, organic molecules, and radioactive isotopes (Chauhan, 2010; Durrani, Hassan, Baloch, & Hameed, 2004; Narwaria & Kush, 2012). Human activities, both industrial and agricultural, have strongly increased the amount of biologically active nitrogen compounds and sulfur (iv) oxides. Various compounds of nitrogen pollute the air, mainly nitric oxide (NO), NO₂, and NH₃ as dry deposition and NO₃⁻ and NH₄⁺ as wet deposition. High concentrations of SO₂ can produce acute injury in the form of foliar necrosis, even after relatively short duration exposure (Seyyednejad, Niknejad, & Yusefi, 2009). The increasing anthropogenic activity intensifies the emission of various pollutants into the environment and introduces different types of harmful substances into the atmosphere. Air pollution is aesthetically unfriendly and can pose health hazards to human as well as plants (Agbaire & Akporhonor, 2014).

Air pollution can directly affect plant via leaves or indirectly via soil acidification. Most plants experience physiological changes before exhibiting visible damage to leaves when exposed to air pollutants (Liu & Ding, 2008). These pollutants in combinations cause greater or synergistic effects to plant growth. The deposition of trace elements, gaseous pollutants, nitrogen oxides (NOₓ), carbon monoxide (CO), carbon dioxide (CO²), and sulfur dioxide (SO₂) on the leaves of plants, affected their physiological behavior (Van Wittenberghe et al., 2013). Pollutants can cause leaf injury, stomata damage, premature senescence, decrease photosynthetic activities, disturb membrane permeability, and reduce growth and yield in sensitive plant species (Tiwari, Agrawal, & Marshall, 2006).

Municipal solid waste (MSW) generation has been increasing at an annual rate of 8–10%, with over 150 million tonnes of MSW being produced each year (Jimoda, Adeniran, Sonibare, & Ayandiran, 2013). A number of gaseous pollutants including carbon monoxide (CO), sulfur dioxide (SO₂), chlorofluorocarbons (CFCs), nitrogen oxides (NOₓ) and volatile organic compounds (VOCs) have been reported to be emitted from municipal solid waste dumpsites (Jimoda et al., 2013; Rim-Rukeh, 2014). Ibadan has over the years experienced population explosion leading to increasing annual rate of solid waste generation.

Pollutants emitted into the atmosphere from combustion of municipal solid waste at dumpsites have major effects on phenology, periodicity, fruiting, flower development, leaf senescence and leaf surface wax characteristics, biomass production, seed germination, seedling growth, physiological, and biochemical characteristics and plant growth (Iqbal, Shafig, Qamar Zaidi, & Athar, 2015). Plants show varying degree of sensitivity and tolerance to air pollution stress. Chlorophyll content (Flowers, Fiscus, & Burkey, 2007); ascorbic acid content (Hoque, Banu, & Okuma, 2007); leaf pH (Klumpp, Furlan, Domingos, & Klumpp, 2000); and relative water content (Rao, 2006) have been used in the evaluation of the impact of air pollution on plants.

Chlorophyll plays a crucial role in photosynthesis (Sadaoka, Kashimura, & Saga, 2011). Chlorophyll catabolism not only affects the key components of a plant’s photosynthesis systems, but it is also responsible for the green color of leaves and fruits and therefore, it plays an important role in plant development (Peng, Xie, Jiang, Song, & Xu, 2013). Ascorbic acid plays an important role in cell wall synthesis, defense, and cell division. It also plays an important role in photosynthetic carbon fixation (Agbaire & Esiefarienhe, 2009). Quantification of chlorophyll and ascorbic acid contents provide...
useful insights into the physiological performance of plants (Girma, Skidmore, de Bie, Bongers, & Schlerf, 2013).

A search of the literature revealed that there is paucity of information about the effects of air pollutants on the chlorophyll and ascorbic acid contents of plants growing within the vicinity of dumpsites in Ibadan, Nigeria. This study therefore aims at investigating the effects of air pollutants emitted at the four major dumpsites in Ibadan, Nigeria, on the ascorbic acid and chlorophyll contents of two medicinal plants (Chromolaena odorata and Morinda lucida) growing naturally within the vicinity of the dumpsites.

2. Materials and methods

2.1. Description of study area
Ibadan is located at longitude 7°2′ and 7°40′E and latitude 3°35′ and 4°10′N, and was founded in 1829. It is approximately 128 km northeast of Lagos and 345 km southwest of Abuja, the federal capital. Like other parts of Nigeria, Ibadan experiences two local climates (rainy and dry seasons). The rainy season runs from March to October and the dry season is from November to February, with highest rainfall of 170 mm (6.69 inches) in the month of September. Temperature in Ibadan ranges from 21 to 35°C (69.8–95°F).

The study was carried out at the four major dumpsites legally approved by the government of Oyo State, Nigeria, for the disposal of municipal solid waste in Ibadan. The dumpsites include: Aba-Eku, Ajakanga; Awotan, and Lapite dumpsites. Figure 1 is a map of Ibadan showing the four legally approved dumpsites.

Aba-Eku (also known as Afofunra) dumpsite is located along Akanra-Ijebu Igbo road in an area of over 10 hectares (0.10 km²) of land. It is located in Ona-Ara local government area of Oyo State. The dumpsite lies between latitude 7°19′ 26″ N and longitude 3°59′ 11″ E. Ajakanga dumpsite is located over an approximate 10 hectares (0.10 km²) of land along Challenge road in Oluyole local government area of Oyo State. The dumpsite lies between latitude 7°18′ 45″ N and longitude 3°51′ 26″ E. Awotan (also known as Apete) dumpsite is situated along Akufo – Ibadan Polytechnic road over an approximate 25 hectares (0.25 km²) of land. It is located in Apete, Ido local government area of Oyo State. The dumpsite lies between latitude 7°27′ 48″ N and longitude 3°50′ 56″ E. Lapite dumpsite is situated over an approximate 20 hectares (0.2 km²) of land. It is located beyond Moniya along Oyo road in Akinyele local government area. The dumpsite lies between latitude 7°34′ 08″ N and longitude 3°54′ 39″ E. All the four dumpsites are owned by Oyo State Solid Waste Management Authority, Ibadan, Nigeria, and are very active.

2.2. Sample collection
Fresh leaves were separately collected from 10 Morinda lucida plant and 10 C. odorata plant growing within the vicinity of the four dumpsites in Ibadan (i.e. Aba-Eku, Ajakanga; Awotan and Lapite dumpsites) and from a control site (Botanical Garden, University of Ibadan, Nigeria which lies between latitude 7°26′ 35″ N and longitude 3°54′ 12″ E). Replicates of fully mature leaves of M. lucida and C. odorata were collected, put in polythene bags, and marked with masking tape. These were immediately taken to the laboratory for analysis. Composite sample of eight leaves for each plant species were used for the analysis. Care was taken to ensure all plants undergoing investigation had isoecological conditions with respect to light, water, soil, and pollutant exposure. Plant sampling was done in May 2015. Identification of the plant samples was done at the University of Ibadan Herbarium.

2.3. Determination of chlorophyll and ascorbic acid contents
Chlorophyll was extracted from the leaves of M. lucida and C. odorata and its level was determined by method as described by Lichtenthaler (1987). About 1.0 g of fresh leaves was blended with a little quantity of distilled water and extracted with 10 ml of 80% (v/v) acetone and left for 15 mins. The liquid portion was decanted into another test tube and centrifuged at 2,500 rpm for 3 min. The
supernatant was collected and 1 ml of the solution was used for the determination of chlorophyll content. The absorbance of the extract was measured at 663 nm and 645 nm with Spectrumlab 725s UV/Visible spectrophotometer using cell with 1-cm path length against 80% (v/v) acetone blank. The levels of chlorophyll A, chlorophyll B, and total chlorophyll (A + B) in the leaves extracts were calculated using Equations (1)–(3), respectively:

\[
\text{Chlorophyll A (mg/g)} = \left(12.7D_{663} - 2.69D_{645}/1000 \times W\right) \times V
\]

\[
\text{Chlorophyll B (mg/g)} = \left(22.9D_{645} - 4.68D_{663}/1000 \times W\right) \times V
\]

\[
\text{Total Chlorophyll} = \text{Chlorophyll A} + \text{Chlorophyll B (mg/g)}
\]

where \(D_{663}\) = absorbance at 663 nm; \(D_{645}\) = absorbance at 645 nm; \(W\) = fresh weight of leaf sample taken (1 g); \(V\) = volume of leaf extract (10 ml).
Ascorbic acid content was determined using the spectrophotometric method of Bajaj and Kaur (1981). About 1 g of fresh leaves of the plant species was put in a test tube, 4 ml of oxalic acid–EDTA extracting solution was added, followed by 1 ml of orthophosphoric acid and 1 ml 5% tetraoxosulphate (vi) acid. To the resulting mixture, 2 ml of ammonium molybdate was added followed by 3 ml of deionized water. The solution was then allowed to stand for 15 min and the absorbance of the resulting solution was measured at 760 nm with Spectrumlab 725s UV/Visible spectrophotometer using cell with 1-cm path length. The concentration of the ascorbic acid in the sample was then extrapolated from a standard curve.

At least three readings of samples were taken, each sample was replicated twice and the entire experiment repeated once. The results obtained were analyzed statistically using single-factor analysis of variance (ANOVA) in order to determine significant differences between the dumpsites and control sites. Pearson's correlation coefficient calculations were used to establish relationships between:

(i) The amount of municipal solid waste generation and chlorophyll A content in leaves of plant species.
(ii) The amount of municipal solid waste generation and chlorophyll B content in leaves of plant species.
(iii) The amount of municipal solid waste generation and the total chlorophyll content in leaves of plant species.
(iv) The amount of municipal solid waste generation and the ascorbic acid content in leaves of plant species.

3. Results and discussion

The summary of total municipal solid waste generation in the four dumpsites in Ibadan, Nigeria, for three years (2012, 2013, and 2014) is presented in Table 1. The data presented in Table 1 show increasing order of municipal solid waste generation at the four dumpsites in Ibadan as Awotan < Lapite < Aba-Eku < Ajakanga.

Figure 2 compares the chlorophyll A contents of *C. odorata* and *M. lucida* collected at the four dumpsites in Ibadan, Nigeria with those collected at the control site. As shown in Figure 2, the level of chlorophyll A in the leaves of *C. odorata* collected at the dumpsites in Ibadan, Nigeria, ranged from 0.94 to 1.58 mg/g. These values were lower than the chlorophyll A content recorded in the leaves of *C. odorata* collected at the control site. The figure also shows that a range of 1.51–2.54 mg/g was recorded as the chlorophyll A content in the leaves of *M. lucida* collected at the four dumpsites in Ibadan, Nigeria, while a value of 2.95 mg/g was recorded in the leaves of *M. lucida* collected at the control site. Results of single-factor analysis of variance (ANOVA) as contained in Table 2 revealed significant difference (*p* = 0.0000801; 0.0000291) among the chlorophyll A contents in the leaves of *C. odorata* and *M. lucida* collected from the four dumpsites and control site.

| Dumpsite | 2012  | 2013  | 2014  | Total  | Average |
|----------|-------|-------|-------|--------|---------|
| Aba-Eku  | 320,320.86 | 124,326.04 | 121,608.81 | 584,255.71 | 194,751.90 |
| Ajakanga | 251,876.51 | 197,770.78 | 164,846.09 | 614,493.38 | 204,831.13 |
| Awotan   | 107,001.49 | 63,719.51 | 63,358.27 | 234,079.27 | 78,026.42 |
| Lapite   | 183,194.72 | 182,630.63 | 153,496.51 | 519,321.86 | 173,107.29 |
| Total    | 862,393.58 | 586,446.96 | 503,309.68 | 1,952,150.22 | 650,716.74 |

Source: Oyo State Solid Waste Management Authority, Agodi Gate, Ibadan, Nigeria.
The levels of chlorophyll B in the leaves of *C. odorata* and *M. lucida* collected at the four dumpsites were compared with the levels recorded in the leaves of the plant species collected at the control site and represented in Figure 3. Figure 3 shows that the levels of chlorophyll B recorded in the leaves of *C. odorata* collected at Aba-Eku, Ajakanga, Awotan and Lapite dumpsites, respectively, were 0.77,
0.74, 1.24, and 0.88 mg/g, while the leaves of *C. odorata* collected at the control site has a value of 1.87 mg/g. Figure 3 further reveals that the chlorophyll B content in the leaves of *M. lucida* collected at the dumpsites ranged from 1.19 to 1.99 mg/g, while the leaves collected at the control site has a value of 2.31 mg/g. Single-factor analysis of variance as presented in Table 2 showed that significant difference ($p = 0.0000321; 0.0000458$) exist among the chlorophyll B contents in the leaves of *C. odorata* and *M. lucida*, respectively, collected from the four dumpsites and control site.

In Figure 4, the total chlorophyll contents in the leaves of *C. odorata* and *M. lucida* collected at the four dumpsites in Ibadan, Nigeria, were compared with those collected at the control site. As Figure 4 reveals, the total chlorophyll content in the leaves of *C. odorata* collected at the four dumpsites ranged from 1.68 to 2.82 mg/g, while the total chlorophyll content recorded in the leaves of *C. odorata* collected at the control site was 4.28 mg/g. On the other hand, the total chlorophyll content in the leaves of *M. lucida* collected at the four dumpsites ranged from 2.70 to 4.53 mg/g which were
observed to be lower than 5.26 mg/g level recorded in the leaves of *M. lucida* collected at the control site as represented in Figure 4. Table 2 showed that there was significant difference (*p* = 0.0000147; 0.0000737) among the total chlorophyll contents in the leaves of *C. odorata* and *M. lucida* respectively collected from the four dumpsites and control site.

Generally, highest levels of chlorophyll A, chlorophyll B, and total chlorophyll were recorded in the leaves of *C. odorata* and *M. lucida* collected at the control site, while the least levels were recorded in the leaves of the two plant species collected at Ajakanga dumpsite. Furthermore, the decreasing order of levels of chlorophyll A, chlorophyll B, and total chlorophyll in the leaves of *C. odorata* and *M. lucida* collected from the various sites is control site > Awotan dumpsite > Lapite dumpsite > Aka-Eku dumpsite > Ajakanga dumpsite. Results of Pearson’s correlation coefficient as shown in Table 2 revealed that negative correlations exist between the amount of municipal solid waste generation and the levels of chlorophyll A (*r* = −0.9999 and −0.9997), chlorophyll B (*r* = −0.9995 and −0.9999), and total chlorophyll (*r* = −0.9995 and −0.9998) in the leaves of *C. odorata* and *M. lucida*, respectively, collected at the four dumpsites in Ibadan, Nigeria.

Figure 5 compares the ascorbic acid content of *Chromolaena odorata* and *Morinda lucida* collected at the four dumpsites in Ibadan, Nigeria with those collected at the control site. As shown in the figure, the ascorbic acid content in the leaves of *C. odorata* collected at the dumpsites in Ibadan, Nigeria, ranged from 1.09 to 1.83 mg/g. The ascorbic acid content recorded in the leaves of *C. odorata* collected at the control site was 1.52 mg/g which was lower than the value recorded at Awotan dumpsite but higher than values recorded at the other dumpsites. Figure 5 also shows that a range of 1.21–2.03 mg/g was recorded as the ascorbic acid content in the leaves of *M. lucida* collected at the four dumpsites in Ibadan, Nigeria, while a value of 1.63 mg/g was recorded in the leaves of *M. lucida* collected at the control site which was lower than the value recorded at Awotan dumpsite but higher than values recorded at the other dumpsites. Statistical analysis revealed significant difference (*p* = 0.000229; 0.000107) among ascorbic acid contents in the leaves of *C. odorata* and *M. lucida* collected from the four dumpsites and control site.

The decreasing order of ascorbic acid content in the leaves of *C. odorata* and *M. lucida* collected from the various sites is Awotan dumpsite > control site > Lapite dumpsite > Aba-Eku dumpsite > Ajakanga dumpsite. Coefficient of correlation calculations (Table 2) revealed that negative correlations exist between the amount of municipal solid waste generation and the ascorbic acid content.
contents \( (r = -0.9997 \text{ and } -0.9998) \) in the leaves of \textit{C. odorata} and \textit{M. lucida}, respectively, collected at the four dumpsites in Ibadan, Nigeria.

Table 3 compares the total chlorophyll and ascorbic acid contents in the leaves of plant species obtained in this study with values obtained from some other studies. Reduction in chlorophyll A, chlorophyll B, total chlorophyll, and ascorbic acid contents in the tissues of different plant species occurred between control and polluted sites in similar studies conducted by Seyyednejad et al. (2009), Tanee and Albert (2013) and Iqbal et al. (2015). However, Agbaire and Esiefarienrhe (2009), Agbaire and Akporhonor (2014), and Lohe et al. (2015) reported increase in chlorophyll A, chlorophyll B, total chlorophyll, and ascorbic acid contents in the tissues of different plant species between control and polluted sites in similar studies.

The percentage reductions in photosynthetic pigments (chlorophyll A, chlorophyll B, and total chlorophyll) as well as ascorbic acid contents obtained in the leaves of \textit{C. odorata} and \textit{M. lucida} due to air pollutants’ emission from municipal solid waste at the four dumpsites in Ibadan, Nigeria as compared to the control site are shown in Table 4.

### Table 3. Comparing total chlorophyll and ascorbic acid contents (mg/g) obtained in this study to values obtained in some other places

| Place/Country | Chlorophyll A | Chlorophyll B | Total chlorophyll | Ascorbic acid |
|---------------|---------------|---------------|------------------|--------------|
| Ughelli, Nigeria | 2.03–4.09 | 6.30–9.54 | 0.09–0.80 | 0.09–0.15 |
| Khuzestan, Iran | 20.8 | 25.43 | NA | NA |
| Oyigbo, Nigeria | 1.17–6.278 | 0.359–5.009 | 0.21–1.787 | 0.24–1.66 |
| Ovian-Aladja, Nigeria | 38.16–61.34 | 29.48–77.75 | 0.30–0.45 | 0.35–0.52 |
| Karachi, Pakistan | 0.500–0.591 | 0.312–0.581 | NA | NA |
| Dehradun, India | 10.04–16.08 | 10.14–16.18 | 3.96–23.09 | 4.04–23.53 |
| Ibadan, Nigeria | 4.28–5.26 | 1.68–4.53 | 1.52–1.63 | 1.09–2.03 |

Note: NA = not available.

### Table 4. Percentage reduction in ascorbic acid and chlorophyll contents of \textit{C. odorata} and \textit{M. lucida} naturally growing within dumpsites as compared to control site

| Plant species | Dumpsite | Chlorophyll A | Chlorophyll B | Total chlorophyll | Ascorbic acid |
|---------------|----------|---------------|---------------|------------------|--------------|
| \textit{C. odorata} | Aba-Eku | 58.92 | 58.82 | 58.88 | 25.00 |
| | Ajakanga | 61.00 | 60.43 | 60.75 | 28.29 |
| | Awotan | 34.44 | 33.69 | 34.11 | +20.39 |
| | Lapite | 53.94 | 52.94 | 53.50 | 15.13 |
| \textit{M. lucida} | Aba-Eku | 46.10 | 45.89 | 46.01 | 22.09 |
| | Ajakanga | 48.81 | 48.48 | 48.67 | 25.77 |
| | Awotan | 13.90 | 13.85 | 13.88 | +24.54 |
| | Lapite | 39.32 | 39.39 | 39.35 | 12.23 |

Note: + indicates percentage increase.
As shown in Table 4, highest percentage reduction of chlorophyll A, chlorophyll B, and total chlorophyll contents in the leaves of *C. odorata* and *M. lucida* were recorded in the plant species collected at Ajakanga dumpsite. On the other hand, the least reduction in chlorophyll A, chlorophyll B, and total chlorophyll contents were recorded in the leaves of *C. odorata* and *M. lucida* collected at Awotan dumpsite. Chlorophyll plays an important role in plant growth. It is one of the essential parts of energy production in green plants and their amounts are significantly affected by environmental condition (Speeding & Thomas, 1973). Depletion in chlorophyll causes a decrease in productivity of plant and subsequently exhibit poor vigor. The total chlorophyll level in plants decreases under stress condition (Speeding & Thomas, 1973). The combustion of municipal solid waste at dumpsites generates a variety of gaseous air pollutants (such as SO₂, NOₓ, CO, NH₃, VOCs, H₂S, etc.) which contaminate the ambient air. The reduction observed in the chlorophyll A, chlorophyll B, and total chlorophyll contents in the leaves of *C. odorata* and *M. lucida* collected from the four dumpsites as compared to the control site could therefore be attributed to the emission of air pollutants from municipal solid waste.

Hamid and Jawaid (2009) reported that different concentrations of SO₂ + NOₓ mixture showed significant changes in the chlorophyll content of *Glycine max* leaves. The deposition of pollutants on the surface of leaves have been observed to cause clogging of stomata which ultimately causes reduction in photosynthetic rate leading to reduction in sugar, chlorophyll, and protein contents (Joshi & Swami, 2009; Narwaria & Kush, 2012; Prajapati & Trpathi, 2008). Furthermore, pollutants have been reported to inhibit the photosynthetic activity of plants growing in polluted environment resulting in depletion of chlorophyll and carotenoid contents of leaves of plants (Chauhan & Joshi, 2008). Therefore, the reduction observed in the chlorophyll A, chlorophyll B, and total chlorophyll contents in the leaves of *C. odorata* and *M. lucida* collected from the four dumpsites in Ibadan, Nigeria, were in agreement with the results of some authors in studies conducted in some other places.

Ascorbic acid plays an important role in cell wall synthesis, defense, and cell division. It also plays an important role in photosynthetic carbon fixation. Ascorbic acid is a strong reductant and it activates many physiological and defense mechanisms in plants. Its reducing power is directly proportional to its concentration (Agbaire & Esiefarienrhe, 2009; Raza & Murthy, 1988). Ascorbic acid is a natural detoxicant which prevent the damaging effect of air pollutants in plant tissues (Singh, Rao, Agrawal, Pandey, & Naryan, 1991) and high amounts favors tolerance in plants. The reducing activity of ascorbic acid is pH-dependent, being more at higher pH levels because high pH increases the efficiency of conversion of hexose sugar to ascorbic acid and is related to the tolerance to pollution (Liu & Ding, 2008).

Results presented in Table 4 show that the highest reduction in ascorbic acid content occurred in the leaves of *C. odorata* and *M. lucida* collected from Ajakanga dumpsite, while the least ascorbic acid content was recorded in the leaves of the plant species collected at Lapite dumpsite. However, increases of 20.39% and 24.54%, respectively, occurred in the leaves of *C. odorata* and *M. lucida* collected from Awotan dumpsite. Tanee and Albert (2013) have similarly observed a reduction in the content of ascorbic acid in plant samples collected at polluted sites when compared to control site. According to them, lower ascorbic acid contents were associated with lower pH of the leaves of plant samples. Similarly, Scholz and Reck (1977) have reported that in the presence of acidic pollutants, the leaf pH is lowered and the decline is greater in sensitive species. A shift in cell sap pH towards the acid zone in the presence of acidic pollutants might decrease the efficiency of conversion of hexose sugar to ascorbic acid (Agrawal, 1988). Pollution of dumpsite environments is associated with the emission of various air pollutants, including acidic gasses such as SO₂, NOₓ, H₂S, etc.; thus, the reduction observed in the ascorbic acid content of *C. odorata* and *M. lucida* collected from the four dumpsites compared to the control site could be attributed to the deposition of acidic gasses on the surface of their leaves.

*C. odorata* and *Morinda lucida* have many medicinal uses and these have been widely reported by many authors (Akubue, 1986; Ettarh & Emeka, 2004; Igoli, Igwue, & Igoli, 2004; Kamanyi, Njamen, &
Exposure of plants to air pollutants has significantly resulted in their morphological and physiological injuries as well as biochemical changes (Agrawal, 1988; Assadi, Pirbalouti, Malekpoor, Teimori, & Assadi, 2011; Chauhan & Joshi, 2008; Hamid & Jawaid, 2009; Joshi & Swami, 2007; Prajapati & Tripathi, 2008; Seyyednejad et al., 2009; Tanee and Albert, 2013). Some of the reported biochemical changes include reduction in chlorophyll, carotenoid, soluble sugar, proline, ascorbic acid, and protein contents of plants.

4. Conclusion
The results obtained from this study revealed that there was an enhanced reduction in the ascorbic acid and chlorophyll (chlorophyll A, chlorophyll B, and total chlorophyll) contents of C. odorata and M. lucida naturally growing within the vicinity of four dumpsites located in Ibadan, Nigeria (Aba-Eku, Ajakanga, Awotan, and Lapite) in comparison to the control site (The Botanical Garden, University of Ibadan, Nigeria). The reduction in the ascorbic acid and chlorophyll contents was attributed to the deposition of air pollutants emitted from the municipal solid waste at the four dumpsites on the leaves of the plant species. Highest reduction effect in the ascorbic acid and chlorophyll contents were observed in C. odorata and M. lucida collected from Ajakanga dumpsite which receives highest amount of municipal solid waste annually. Air pollutants emission at the four dumpsites caused significant percentage reduction in the ascorbic acid and chlorophyll (chlorophyll A, chlorophyll B, and total chlorophyll) contents of C. odorata and M. lucida in the following decreasing order Ajakanga dumpsite > Aba-Eku dumpsite > Lapite dumpsite > Awotan dumpsite. Pearson’s correlation coefficient calculations showed negative relationship between municipal solid waste generation and chlorophyll contents on one hand; and between municipal solid waste generation and ascorbic acid contents on the other. The reductions observed in the chlorophyll and ascorbic acid contents of C. odorata and M. lucida collected at the four dumpsites compared to those collected at the control site could be attributed to the deposition of air pollutants emitted from municipal solid waste on the two plant species.

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