Scientific Research Publishing

Open Journal of Air Pollution, 2021, 10, 53-62
https://www.scirp.org/journal/ojap
ISSN Online: 2169-2661
ISSN Print: 2169-2653

Determination of Air Pollutant Concentrations in Plant Species in Relation to Pollution Sources

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How to cite this paper: Atator, L.T., Kamou, H., Bawa, A., Agbodan, K.M.L., Polo, A.A., Akpavi, S.B. and Akpagana, K. (2021) Determination of Air Pollutant Concentrations in Plant Species in Relation to Pollution Sources. *Open Journal of Air Pollution*, **10**, 53-62.
https://doi.org/10.4236/ojap.2021.103004

Received: August 9, 2021
Accepted: September 27, 2021
Published: September 30, 2021

Abstract

Air quality has been a major health issue in urban areas in recent decades. Human activities release a large number of pollutants into the atmosphere which has a direct impact on plant health and leads to ecosystem degradation. The objective of this study is to contribute to a better evaluation of the impact of the air quality of the city of Togo on biological resources. The determination of pollutants was done on samples of plant species with a strong link with the source of pollution. The determination of Sulfur dioxide (SO_2) was done by the ripper method. The determination of carbon and estimation of CO_2 and CO by the colorimetric method. The determination of nitrogen was done by the Kjeldhal method. The results showed that at the industrial level the amount of CO_2 in *Alternanthera repens* is high with a value of 53.3911 mg/ml. On the other hand, the quantity of CO in *Senna occidentalis* is 44.3619 mg/ml. In *Pithecellobium dulce*, the quantity of SO_2 and NO_2 are evaluated respectively to 0.1588 mg/ml and 0.3696 mg/ml. Regarding to the dumps, the quantity of CO_2 in *Newbouldia laevis* is very high with a value of 65.8508 mg/ml. On the other hand the amount of CO in *Senna occidentalis* is 51.6106 mg/ml. The quantity of SO_2 in *Newbouldia laevis* is 0.2101 mg/ml and NO_2 in *Ocimum canum* is 0.2744 mg/ml. At the level of roads, the quantities of CO_2 and CO in *Eragrostis tenella* are very high with values respectively equal to 74.4092 mg/ml and 62.2654 mg/ml. On the other hand, the amount of NO_2 in *Amaranthus* sp is 0.2304 mg/ml and that of SO_2 in *Eragrostis Tenella* is 0.1691 mg/ml. The use of a plant bioindicator sensitive to pollutants, allowed concluding that the air of the city of Lome is polluted. The concentration of carbon dioxide and carbon monoxide is much more evident in return when the health of plant species is threatened.

Keywords

Air Pollution, Anthropogenic Pollution Sources, Bio-Sensitive Species, City of Lomé, Togo

1. Introduction

Living organisms are known to reflect environmental conditions according to their sensitivity. This is called biomonitoring, or biological monitoring, using the most sensitive animal or plant species to the pollutants being monitored in their environment. Lichens and mosses are good examples for assessing air pollution [1] [2]. Several approaches have been proposed depending on the observation scale considered [3]. Thus, we distinguish the ecological scale by the biological response of individuals (bio-indication) or communities (bio-integration), from the geochemical scale by the accumulation of contaminant (bioaccumulation). The ecological approach seeks to assess air quality based on the presence/absence of key species in a specific survey (e.g. lichen species). The first scales set up to assess sulfur pollution are no longer appropriate in their present state since the changes in atmospheric contaminants in recent decades [4] [5]. The sensitivity of species must be regularly updated, as already done by [6] towards dominant nitrogen contamination. The analysis of contaminants in an atmospheric deposition is facilitated by the bioaccumulation approach [7]. However, the mechanisms related to the integration of pollutants by plants in Togo and their possible releases are not yet fully documented. For this reason, some plant species were chosen as model organisms in the monitoring of atmospheric contamination in the city of Lomé during the period 2017-2020.

2. Sampling of Plant Species

The analysis of the preponderant pollutants in the city of Lomé made it possible to identify sites or sources of pollution presenting high atmospheric concentrations of certain gases. These results coupled with those determining the species having links with these sources allowed to retain the samples of sources of pollutants presenting high values specific to a pollutant. These sites were sampled for plant species related to the source (**Figure 1**).

Seven (7) species plant with a very strong link to the anthropogenic pollution source were selected for the determination of elements at the Laboratory. They are: *Alternanthera repens*, *Amaranthus* sp, *Eragrotis tenella*, *Senna occidentalis*, *Ocimum canum*, *Newbouldia laevis*, *Pithecellobium dulce*. These samples were kept cool in minigrip bags to avoid water loss and then sent to the laboratory for chemical analysis.

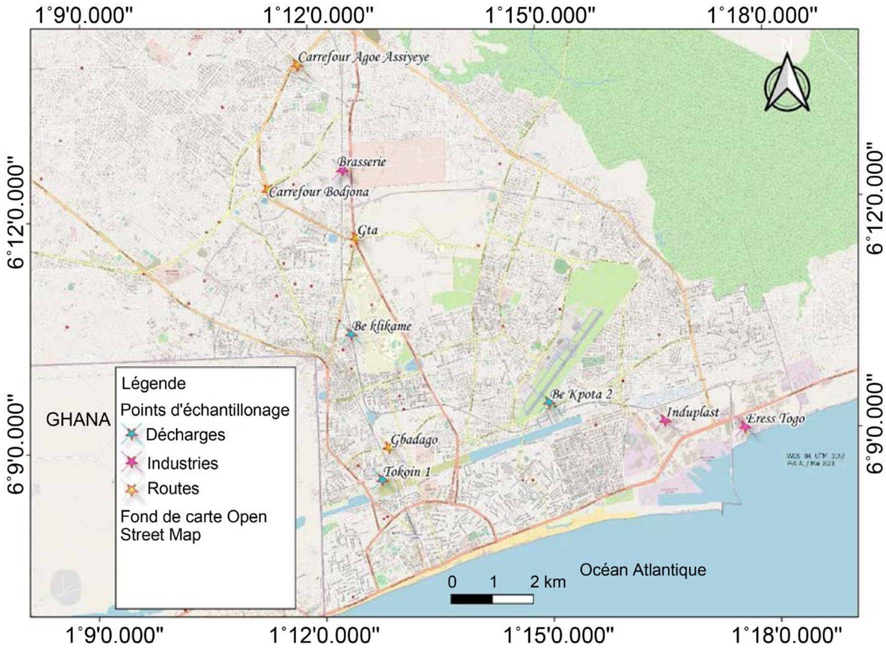

Figure 1. Plant species sampling sites.

3. Determination of Sulfur Dioxide (SO_2) by the Ripper Method

- Principle of determination

SO_2 or sulfur dioxide exists in 2 forms: free and combined. The free form is determined in acid medium by direct iodometric titration and the combined form by the difference between total and free sulfur dioxide. In this analysis, both forms were evaluated. The combined SO_2 is hydrolyzed in alkaline medium.

- Procedure for the titration of the iodine solution

Put 25 ml of the iodine solution into a 250 ml Erlenmeyer flask and titrate with the sodium thiosulfate solution until discoloration. V ml the volume poured.

- Procedure for the determination of free SO2

The sample was ground with a molinex added with distilled water. The obtained substrate was poured into an Erlenmeyer of 250 ml. The solution obtained was filtered and the filtrate constitutes the plant extract. 15 ml of the plant extract was added with 1 ml of starch starch and about 3 ml of sulfuric acid to 1/3. This was titrated with 0.02 N iodine until a persistent blue-brown hue appeared 5 - 10 s. N the volume poured.

4. Procedure for the Determination of Total SO_2

- Decombination of SO_2

15 ml of the plant extract was poured into a 250 ml Erlenmeyer flask containing about 6 ml of 1 M NaOH. The whole was stoppered and shaken. After 10 min of rest of the solution, 1 ml of starch starch and 2 ml of sulfuric acid to 1/3 were added and titrated with 0.02 N iodine until a persistent blue-brown hue appeared after 5 to 10 s. Let N1 ml be the volume poured.

- Total decombination of SO_2

In the previous mixture, 24 ml of NaOH added and stoppered then shake and wait 5 mn. 1 ml of starch starch and 3 ml of sulfuric acid to 1/3 were added. The whole was titrated with 0.02 N iodine until a persistent purple coloration appeared, *i.e.* N2 ml, the volume poured.

- Iodine titration method

$[I2] = [Na_2S_2O_3] \times V \times 1/50 = 0.002 \times V$ (mol/l)

- Determination of SO_2 content

Free $[SO_2]$ mg/l = $64.07 \times [I2] \times N \times 1000/Vext$ or [Free SO_2] mg/l = $42.71 \times N$ [Total SO_2] mg/l = $64.07 \times [I2] \times (N1 + N2) \times 1000/Vext$ or [Total SO_2] mg/l = $42.71 \times (N1 + N2)$ $[SO_2C] = [SO_2T] - [SO_2L]$.

5. Determination of Carbon and Estimation of CO_2 and CO

5.1. Colorimetric Method

Principle of determination: The carbon of the organic matter is oxidized by a mixture of potassium dichromate and sulfuric acid. The blue-green Cr^{3+} ions formed during the oxidation are determined directly by colorimetry reaction and which are proportional to the equivalents of oxidized carbon. The colorimetric titration curve is made against a glucose solution of known carbon content. Aqueous solution of potassium dichromate and concentrated sulfuric acid were used.

5.2. Colorimetric Mode of Determination

A soil sample containing between 0.4 mg and 15 mg of carbon in a 50 ml Erlenmeyer flask was weighed. 5 ml of potassium dichromate and 7.5 ml of concentrated sulfuric acid were added. The whole was covered with a watch glass and then placed in the oven at 105˚C for three hours. After cooling, distilled water was added and made the volume to 40 ml. The whole was shaken and left to decant overnight. A 3500 rpm centrifugation for 10 minutes in a glass tube was done and then weighed with a spectrophotometer at 590 nm. Finally a calibration was done.

5.3. Expression of Results

The percentage of carbon is: $C\% = Lc/Pe \times 0.115$ With: Lc = Curve reading in ppm or mg/l, Pe = Weight of soil (g).

According to the equation $C + O_2 \longrightarrow CO_2$; (12 g C gives 44 g CO_2 and 28 g CO).

6. Determination of Nitrogen by the Kjeldhal Method

6.1 Principle of Dosage

The organic matter has been destroyed by oxidizing attack with sulfuric acid. The nitrogen in its various forms is converted into ammonium sulfate in the presence of a selenium catalyst.

6.2. Method of Extraction and Determination of Nitrogen

0.25 g of plant powder in a matras was weighed and then added with 50 mg of salicylic acid and 6 glass beads. The matron was shaken and 5 cc of concentrated sulfuric acid was added. The matras was stoppered with a funnel. The whole assembly was allowed to stand overnight. 125 mg of plant catalyst was added and stirred. The whole was left until the residue was perfectly white and then allowed to cool. The funnel in the neck of the matron was removed after rinsing it with a squirt. 40 ml of soda 12N was added. The whole was distilled. The distillate was then collected in 25 ml of boric acid in the presence of a turn indicator. The titration was done with N/10 sulfuric acid. 4 drops of indicator were added and titration with N/10 sulfuric acid until green to red was performed. The results were expressed as mg per ml.

7. Results

7.1. At the Industry Level

At the industrial level, *Alternanthera repens* stored more CO_2 with a value of 53.3911 mg/ml. On the other hand, *Pithecellobium dulce* stored more CO with a value of 44.3619 mg/ml. However, NO_2 and SO_2 are revealed present in *Pithecellobium dulce* species with low amounts (Figure 2).

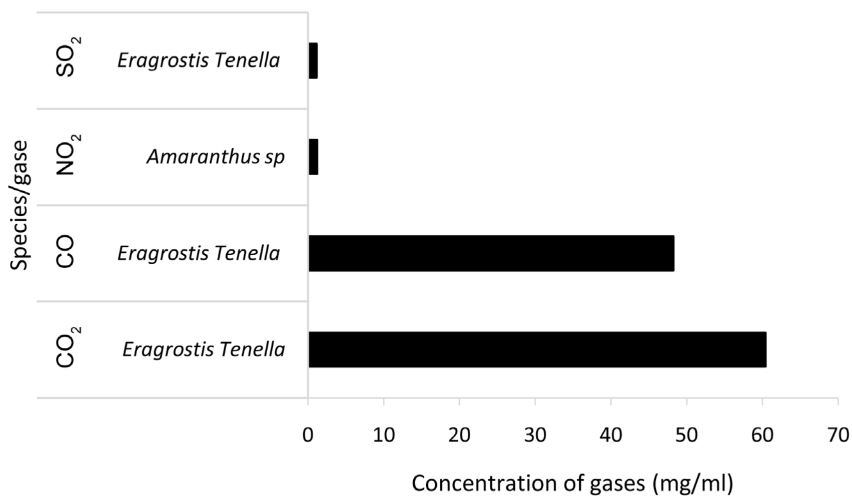

Figure 2. Concentration of the different gases at the level of the species identified at the level of the industries.

7.2. At the Level of Landfills

At the level of landfills, *Newbouldia laevis* stored more CO_2 with a value of 65.8508 mg/ml. On the other hand, *Senna occidentalis* stored more CO with a value of 51.6106 mg/ml. However, NO_2 and SO_2 were found to be present in *Newbouldia laevis* and *Ocimum canum* with low amounts (Figure 3).

7.3. At the Road Level

At the level of roads, *Eragrostis Tenella* stored more CO_2 with a value of 74.4092 mg/ml and CO with a value of 62.2654 mg/ml. However, NO_2 and SO_2 were found to be present in *Amanranthus* sp and *Eragrostis Tenella* but with low amounts (**Figure 4**).

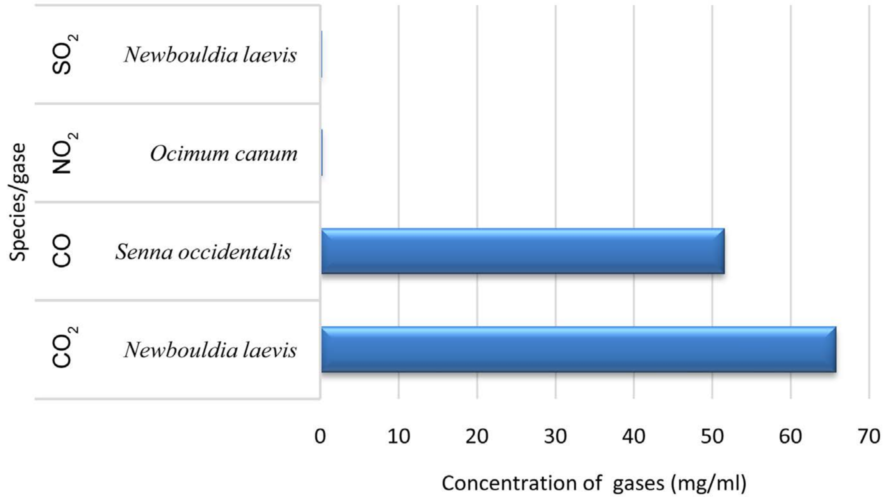

Figure 3. Concentration of the different gases at the level of the species identified at the landfill.

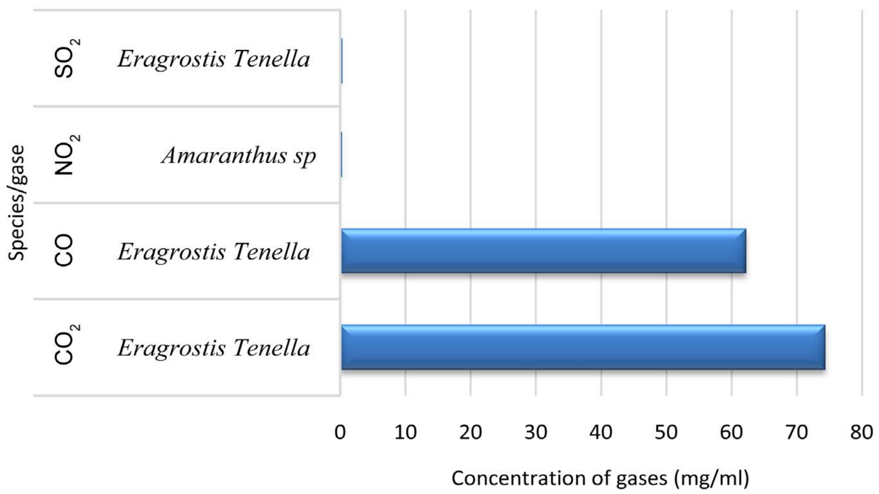

Figure 4. Concentration of the different gases at the level of the species surveyed at the roadsides.

Table 1 and **Table 2** present the detailed results of the different plant species analyzed in relation to the specific sources of air pollution. At the level of industries, the amount of CO_2 in *Alternanthera repens* is very high with a value of 53.3911 mg/ml. On the other hand the amount of CO in *Senna occidentalis* is 44.3619 mg/ml/. At the level of *Pithecellobium dulce* the quantity of SO_2 and NO_2 are evaluated respectively to 0.1588 mg/ml and 0.3696 mg/ml. At the level of the discharges, the quantity of CO_2 in *Newbouldia laevis* is very high with a value of 65.8508 mg/ml. On the other hand the amount of CO in *Senna occidentalis* is 51.6106 mg/ml/. At the level of *Newbouldia laevis* the amount of

Table 1. Plant species at sites with high gas-specific values.

Contaminants	Stations	GPS		Species	Results (mg/ml)
		X	Y		
Industries					
SO_2	Induplast	680,393	309,219	*Pithecellobium dulce* (Roxb.) Benth.	0.1588
CO_2	Brasserie	686,678	301,591	*Alternanthera repens* (L.) Link.	53.3911
NO_2	Brasserie	686,678	301,591	*Pithecellobium dulce* (Roxb.) Benth.	0.3696
CO	Eress Togo	680,169	311,168	*Pithecellobium dulce* (Roxb.) Benth.	44.3619
Landfills					
SO_2	Bè Kpota 2	680,931	306,416	*Newbouldia laevis* (P. Beauv.) Seemann ex Bureau	0.2101
CO_2	Bè Kpota 2	680,931	306,416	*Newbouldia laevis* (P. Beauv.) Seemann ex Bureau	65.8508
NO_2	Bè Klikamé	682,744	301,656	*Ocimum canum* Sims	0.2744
CO	Tokoin 1	679,233	302,283	*Senna occidentalis* (L.) Link	51.6106
Roadsides					
SO_2	Gta	6.19447	1.20933	*Eragrostis Tenella* (linn.) P Beauv.	0.1691
CO_2	Carrefour Bodjona	6.20544	1.19025	*Eragrostis Tenella* (linn.) P Beauv.	74.4092
NO_2	Carrefour Agoè Assiyéyé	6.23236	1.19765	*Amaranthus* sp	0.2304
CO	Gbadago	6.14894	1.21504	*Eragrostis Tenella* (linn.) P Beauv.	62.2654

Table 2. Contents of plant species in different chemical elements considered.

Sources of Pollution	Stations	GPS		Species	Results (mg/ml)			
		X	Y		NO_2	SO_2	CO	CO_2
Industries	Induplast	680,393	309,219	*Pithecellobium dulce* (Roxb.) Benth.	0.381	0.159	40.522	63.7442
	Brasserie	686,678	301,591	*Alternanthera repens* (L.) Link.	0.283	0.174	33.94	53.3911
	Brasserie	686,678	301,591	*Pithecellobium dulce* (Roxb.) Benth.	0.37	0.185	45.074	70.9044
	Eress Togo	680,169	311,168	*Pithecellobium dulce* (Roxb.) Benth.	0.375	0.128	44.362	69.785
Landfills	Bè Kpota 2	680,931	306,416	*Newbouldia laevis* (P. Beauv.) Seem.	0.375	0.21	41.861	65.85
	Bè Klikamé	682,744	301,656	*Ocimum canum* Sims	0.274	0.108	36.731	57.780
	Tokoin 1	679,233	302,283	*Senna occidentalis* (L.) Link	0.325	0.133	51.611	81.187
Roadsides	GTA	619,447	120,933	*Eragrostis Tenella* (linn. P Beauv.	0.358	0.169	62.265	97.948
	Carrefour Bodjona	620,544	119,025	*Eragrostis Tenella* (linn.) P Beauv.	0.952	0.226	47.302	74.409
	Carrefour Agoè Assiyéyé	623,236	119,765	*Amaranthus* sp	0.23	0.292	29.491	46.392
	Gbadago	614,894	121,504	*Eragrostis Tenella* (linn.) P Beauv.	0.358	0.169	62.265	97.948

SO_2 is 0.2101 mg/ml and NO_2 in *Ocimum canum* is 0.2744 mg/ml.

At the of level of roads, the quantities of CO_2 and CO in *Eragrostis Tenella* are very high with values respectively equal to 74.4092 mg/ml and 62.2654 mg/ml. On the other hand, the amount of NO_2 in *Amaranthus* sp is 0.2304 mg/ml and that of SO_2 in *Eragrostis Tenella* is 0.1691 mg/ml (**Table 1** and **Table 2**).

8. Discussion

Density of the road traffic, landfills and industries are the source of atmospheric pollution worldwide. Gases produced by anthropogenic sources are in turn captured by some plant species in nature. Among the main gases measured at the level of industries, landfills and roads in the city of Lomé, it was revealed a high concentration of these gases at the level of certain plant species. This is the case of [8] [9] in the USA.

At the industrial level, it was found that *Alternanthera repens* stored more carbon dioxide (CO_2) followed by *Pithecellobium dulce* which stored more carbon monoxide (CO). However, SO_2 and NO_2 are stored with low concentrations. In Togo, in the city of Lome, industries are among the sources of pollution where carbon dioxide and carbon monoxide are the most released gases in nature. At the level of these industries the most frequent and widespread species are *Alternanthera repens* and *Pithecellobium dulce*. These species undergo enormous pressures with respect to the gases that are released into the atmosphere. The presence of these gases in these species really shows that in these industrial areas, the atmosphere is polluted. In these industrial areas, sulfur dioxide and nitrogen dioxide are recorded at the level of these same plant species. Indeed according to several authors NO_2 and SO_2 are gases which should not be in the atmosphere. The presence of these gases confirms that the industries constitute sources of anthropic pollutions which are to be taken into account. These same studies were carried out on lichens, mosses, tobacco [4] [5] [8] [9] [10] [11]. Indeed, most of these studies cited above have confirmed that lichens and mosses are very sensitive species that can be used to measure the degree of pollution of the atmosphere in a given area.

At the level of landfills, *Newbouldia laevis* and *Senna occidentalis* are recognized as species that have more accumulated carbon dioxide and carbon monoxide. In contrast the concentration of NO_2 in *Ocimum canum* low as well as the concentration of sulfur dioxide in *Newbouldia laevis*. At road level the concentration of carbon dioxide is higher in *Eragrostis Tenella* and that of carbon monoxide is higher in *Amaranthus* sp.

The comparison of the levels of these gases in the species shows spatial variations of these gases in the city of Lomé. Unfortunately in Togo, several plant species are used extensively by urban, semi-urban and rural populations. And among these species we can cite *Ocimum canum*, *Newbouldia laevis*, *Senna occidenttalis*, *Alternanthera repens*, *Eragrostis tenella*, *Pithecellobium dulce*. According to the [12] WHO (2005) values, the accumulation of pollutants in plants can cause carcinogenic diseases in human organism.

Thus, our study on biomonitoring in the city of Togo, carried out from the observation of its effects on these sensitive plants, confirms the influence of urban road traffic density, anthropic activities and climatic conditions. Our results, which are in agreement with ozone data measured continuously by AIRLOR on some urban and suburban sites in France, complete the knowledge of the situation of an important regional agglomeration with respect to these atmospheric pollutants.

9. Conclusion

The results showed that at the industrial level the concentration of CO_2 in *Alternanthera repens* is high with a value of 53.3911 mg/ml. On the other hand, the quantity of CO in *Senna occidentalis* is 44.3619 mg/ml. At the level of *Pithecellobium dulce*, the quantity of SO_2 and NO_2 are evaluated respectively to 0.1588 mg/ml and 0.3696 mg/ml. At the level of the dumps, the amount of CO_2 in *Newbouldia laevis* is very high with a value of 65.8508 mg/ml. On the other hand, the amount of CO in *Senna occidentalis* is 51.6106 mg/ml. At the level of *Newbouldia laevis* the amount of SO_2 is 0.2101 mg/ml and NO_2 in *Ocimum canum* is 0.2744 mg/ml. At the level of roads, the quantities of CO_2 and CO in *Eragrostis Tenella* are very high with values respectively equal to 74.4092 mg/ml and 62.2654 mg/ml. On the other hand, the amount of NO_2 in *Amaranthus* sp is 0.2304 mg/ml and that of SO_2 in *Eragrostis Tenella* is 0.1691 mg/ml. The use of a plant bioindicator sensitive to pollutants, allowed concluding that the air of the city of Lome is polluted. The concentration of carbon dioxide and carbon monoxide is much more evident in return the health of plant species is threatened.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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