World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Assessment of urban air quality in Abidjan in terms of trace metals (copper, lead, zinc) by arborescent vegetation: Case of the species Hibiscus tiliaceus rubra.

Stephane Koffi Kouamé [1], Dobi-Brice Kouadio Kouassi [1], Zoungranan Yacouba [2,*], Edmond Ahoua Sika [3], Tchirioua Ekou [1] and Lynda Ekou [1]

[1] *Department of Chemistry, University NANGUI ABROGOUA, Abidjan, Côte d'Ivoire.*
[2] *Department of Mathematics, Physics and Chemistry, University Peleforo GON COULIBALY, Korhogo, Côte d'Ivoire.*
[3] *Department of Environmental Sciences, University NANGUI ABROGOUA, Abidjan, Côte d'Ivoire.*

World Journal of Advanced Research and Reviews, 2024, 22(02), 744–752

Publication history: Received on 31 March 2024; revised on 06 May 2024; accepted on 08 May 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.2.1411

Abstract

Urban air quality is closely linked to human activities. Policies aimed at reducing or monitoring this form of pollution therefore have a dual benefit for health and the environment. Biomonitoring of air quality is one possible scientific approach.

In this study, the woody species Hibiscus tiliaceus rubra was used as a biomonitor of air quality in the city of Abidjan. The leaves of the woody species were used to quantify the bioaccumulation of three trace metals: copper, lead and zinc. The assessment was carried out on five main road sections: "Adjamé-Cocody", " Adjamé-Yopougon", "Cocody-Bingerville", abobo-Anyama" and " Adjamé-Plateau".

The results obtained show that the content of these trace metals varies according to the road. High levels of copper and zinc and very low levels of lead were initially found in the leaves of the species. The Adjamé-Cocody axis and the Adjamé-Yopougon axis recorded the highest levels of lead. The Adjamé-Plateau axis remains the least contaminated, with relatively low levels of lead.

Keywords: Hibiscus tiliaceus rubra; Air pollution; Bioacumulation; Trace Metal Elements

1. Introduction

Air pollution is defined as the presence of harmful substances, particles (solid or liquid) and gases in the ambient air which tend to harm human health or well-being, life animal or plant [1-3]. These pollutants are in chemical or physical form and are generally generated by activities in the agricultural, industrial and automobile transport sectors. In Ivory Coast, strong demographic growth has led to exponential demand in the field of automobile transport [4]. The city of Abidjan (economic capital of Côte d'Ivoire), which concentrates approximately 60 to 85% of industries [2] and according to SICTA approximately 80% of the automobile fleet [5], is not exempt from this phenomenon. pollution [6,7]. Among the polluting substances linked to automobile traffic, there are Metal Trace Elements (ETM).

ETMs are harmful due to their persistent, non-biodegradable and carcinogenic nature. Their presence in high doses is likely to cause dysfunction of the food chain and cause human health problems [8-11].

ETMs emitted into the atmosphere first adhere to particles and dust, then settle on trees and on the ground [12]. The factors that influence the distribution of ETMs in the atmosphere are: the direction and speed of the prevailing wind, the topography of the site, the diameter of the particles and the surface characteristics of the materials on which they

* Corresponding author: Zoungranan Yacouba; Email: zoungranan@gmail.com

are deposited [13]. In view of all of the above, it must be admitted that human health is not only affected by air pollution, but also by water and soil pollution.

It is therefore more than necessary to carry out a continuous environmental monitoring study.

From one compartment of the biosphere to another, there are two methods of monitoring polluting substances, namely direct methods and indirect methods. Whatever the compartment considered, direct methods consist of the direct analysis of samples and their implementation is sometimes costly because they require equipment that is as expensive as it is complex, thus making them inaccessible to developing countries.

Faced with the difficulties of quantifying and monitoring the levels of these polluting substances in the different compartments of the biosphere, scientists are increasingly turning towards indirect methods such as biomonitoring [15,16]. Biomonitoring consists of the use of biological species to detect or reveal the presence of substances that are pollutants. With regard to metallic trace elements (TME), biomonitoring studies with the lichen species [7] were carried out over a period of one year in the atmosphere of the city of Abidjan, and these studies revealed a significant presence of a few ETMs. However, the response duration (1 year) used in these studies turns out to be long in terms of health alert.

The search for biological matrices that are more indicative in terms of response time is important in a context of pollution requiring a health alert.

Due to their larger surface area and structures that can absorb a large number of air pollutants, tree leaves have been widely used for biomonitoring of metals such as buds, flowers and needles [17,18].

It is in this context that the leaves of the plant species Hibiscus tiliaceus rubra were used in this work as a bio-monitor matrix of pollution by some ETMs. Indeed, the plant species Hibiscus tiliaceus rubra is abundantly planted along the main roads of the city of Abidjan.

The objective of the present study is to propose an evaluation of the Hibiscus Tiliaceus species as a biomonitor of metal pollution in the city of Abidjan.

2. Material and methods

2.1. Sampling area

The study took place on traffic axes of the city of Abidjan (5°19' N and 4°01' W), with an area of approximately 324 km^2, in the South-East of Côte d'Ivoire. This city is the site of strong anthropogenic activities likely to contribute to heavy pollution. The specificities of the traffic axes which constitute study sites, such as: the density of road traffic, the presence of industry etc., are presented in Table 1.

Table 1 Specific characteristics of the road axis environment

Axis	**Designation**	**Anthropogenic specificities**
Abobo -Anyama y	Abo-Any	High population density, car traffic, absence of industry nearby
Adjamé -Plateau	Adj-Plat	Lagoon edge, heavy car traffic, bay development work
Adjamé -Cocody	Adj-Coc	Heavy traffic, flower gardens, domestic living spaces
Cocody-Bingerville	Coc-Bing	Absence of industry and heavy automobile traffic
Adjamé -Yopougon	Adj-Yop	Strong presence of industry (textiles, soap works, cement works, oil works), high automobile traffic.

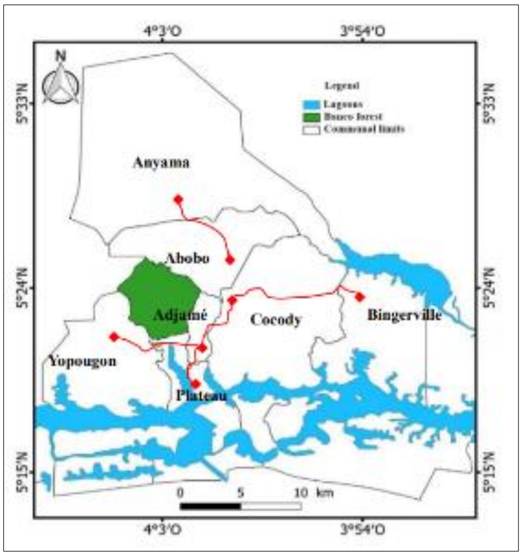

Figure 1 Map of roads axis in the study area

2.2. Biomonitoring plant species

2.2.1. Description

Figure 2 Study species

The study species *Hibiscus tiliaceus rubra* is a tree about 2 to 3 m tall with hairless or stellate hairy brown-gray stems and branches with lenticels. Its leaves are simple and its lanceolate stipules are narrowly oval, about 3.5 cm long. The petiole has a length of 6 cm to 15 cm, the blade oval to orbicular unlobed or rarely lobed [19]. The main veins have a nectary near the base below. The pedicel, 0.5 cm to 2 cm long, is articulated at the base. The petals are free and oval from 4 cm to 7 cm and often yellow with a red base [20]. This plant has numerous stamens fused into a column that can reach 2.5 cm long. The fruit of the species is ovoid and can reach 3 cm long with dense, soft gray hairs. The fruit contains many seeds. These brown seeds are bean-shaped, approximately 4 mm to 2 mm, and rounded in the cotyledon [21].

2.2.2. Systematic overview of the species

The genus *Hibiscus* includes around 200 species, mainly found in tropical and subtropical regions. *Hibiscus tiliaceus rubra* differs from other species by the size of the epicalyx, the shape and hairiness of the leaves and that of the seeds. It is often found near the open sea but sometimes at higher altitudes. It adapts easily to drought [23]. During the day, the flowers turn orange then red before falling. The branches of the tree often bend over time. The leaves are heart-shaped and deep red [24]. Cross sections of the petiole reveal that the shape of the structure varies depending on the height at which the section was obtained [25]. Reproduction occurs sexually through seeds and asexually from stem or branch cuttings. In the case of sexual reproduction, grain formation begins with the deposition of pollen grains on the stigmas of the pistil (pollination). These germinate and form a tube leading the male gametes to the female gametes in the ovary for fertilization. Each fertilized ovule turns into a seed and the pistil turns into a fruit. The flowers, monochrome or two-tone, are twisted before they fully open [20]. The germination rate of seeds is generally around

50% or more when they are directly sown [26]. Regarding the asexual reproduction route, cuttings, 20–45 cm long and 1–3 cm in diameter, are directly planted [27].

Table 2 Systematics of the species [22]

Kingdom :	**Plant**
Division :	Magnoliophyta
Class :	Magnoliopsida
Order :	Malvacées
Family :	Malvaceae
Genus :	Hibiscus
Species:	Hibiscus tiliaceus rubra

2.3. Collection of leaf samples

Three sampling campaigns of fresh Hibiscus tiliaceus rubra rubra leaves were carried out during the study. Samples were taken one month apart. Prior to the first sampling, a preliminary study was carried out to identify 5 trees of the species on each axis, each located between 2.5 m and 3 m from the road. During this preliminary study, emerging leaves were collected at a height of approximately 3 m from the ground and the stem was marked with a nylon string to monitor the development of new leaves. The first campaign took place 1 month after this preliminary study. Among the marked stems, a part of the leaves is sampled, and the rest is left for the following campaigns. All leaves from the tag to the new bud are then harvested. The harvested leaves are placed in paper envelopes and sent immediately to the laboratory.

2.4. Laboratory sample processing

Once in the laboratory, the leaf samples were placed in an incubator (Memmert BM300, Schwabach, Germany) at 105°C for 48 h. For a given site a mass of 0.5 g of dry leaves from each tree on the site was weighed, to constitute a mixture of mass of 1.5 g of dry leaves per site. The resulting mixture of leaves is ground using a porcelain pestle and mortar. Dried lichen samples are ground using a porcelain mortar and pestle. The powder obtained is then mineralized. It was dried again in an oven at 105°C for 4 hours. A quantity of 0.3 g of the dry powder is then taken and placed in a porcelain crucible containing 50 ml of capacity. The sample was calcined in a muffle furnace at 550°C for 4 hours. The ashes obtained are placed in Teflon tubes. A 5:1 (v/v) mixture of hydrochloric acid (20%) and nitric acid (69%) is prepared in the crucibles then poured into the Teflon tubes. The tubes are then placed in a water bath at 80° C for 1 hour. The contents are collected in a 25 mL flask, then supplemented with distilled water to the mark. Samples are analyzed using Atomic Absorption Spectrometer iCE 3400 AAS.

2.5. MET content

The metal content measured in the leaves of the species is determined by calculation using the expression below:

$$\text{MET content (mg/g)} = \frac{(C_s - C_c) \times V}{\text{m}}$$

In this expression:

V (L) is the volume of the solution after mineralization (25 mL)
m (g) is the mass of the mineralized leaves
Cs (mg/L) is the metal concentration in the sample
Cc is the metal concentration in the control sample (buds)

2.6. Data processing

All calculations were performed using STATISTICA software, version 8.0, and Microsoft Office Excel 2016 Professional. Means and standard deviations were calculated from three individual measurements.

3. Results

3.1. MET bioaccumulated per campaign

Figures 3, 4 and 5 show the results of the METs concentrations bioaccumulated in the leaves of the species during the three study campaigns.

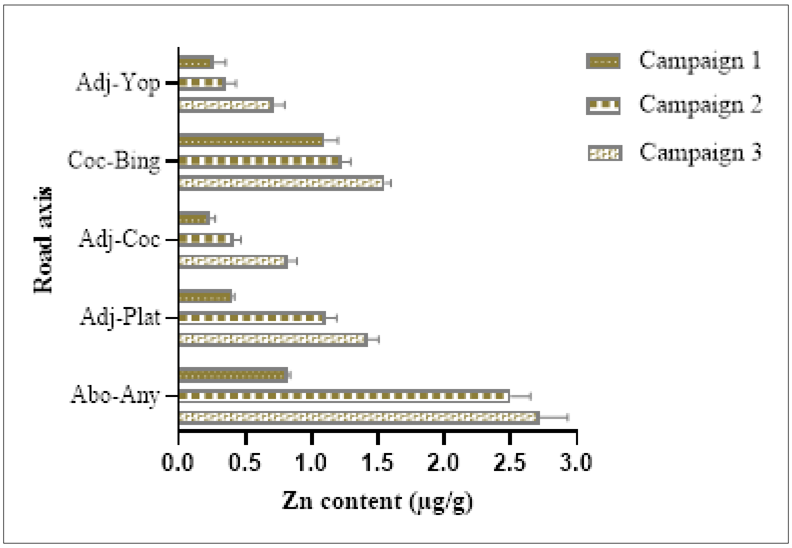

Figure 3 Content of zinc on the different axis during the three campaigns

Analysis of Figure 3 shows that the species Hibiscus tiliaceus rubra has a good affinity for zinc. The values measured are in the order of µg/g. Low levels were observed at the Adjamé-Cocody sites, while high levels were recorded at the Abobo-Anyama site during the second and third surveys. The copper values observed (Fig. 4), were in the order of 10^{-1} µg/g in all the study's roads axis. These occurrences are relatively low compared to those observed for zinc. The distribution is almost homogeneous, with a peak in deposition at the Adjamé-Yopougon site. Overall, the levels measured increased from one campaign to the next, suggesting a good retention capacity for the species. However, the differences observed between the second and third campaigns were not significant.

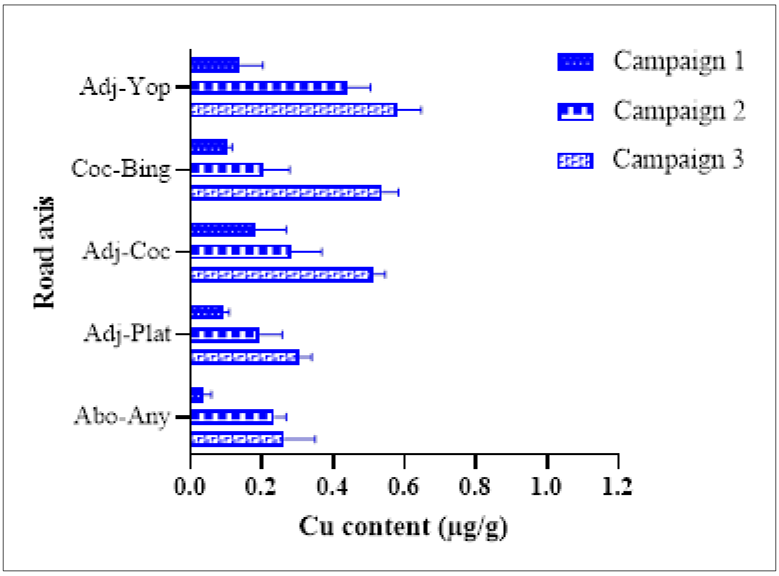

Figure 4 Content of copper on the different axis during the three campaigns

The levels of bioaccumulated lead in the leaves of this species are very low. As lead is not a trace element required for the nutritional metabolism of the plant, its presence could be due to environmental contamination outside the species.

The Adjamé-Yopougon road axis recorded the highest levels observed during the last two seasons. The lowest levels were observed on the Adjamé-Plateau axis.

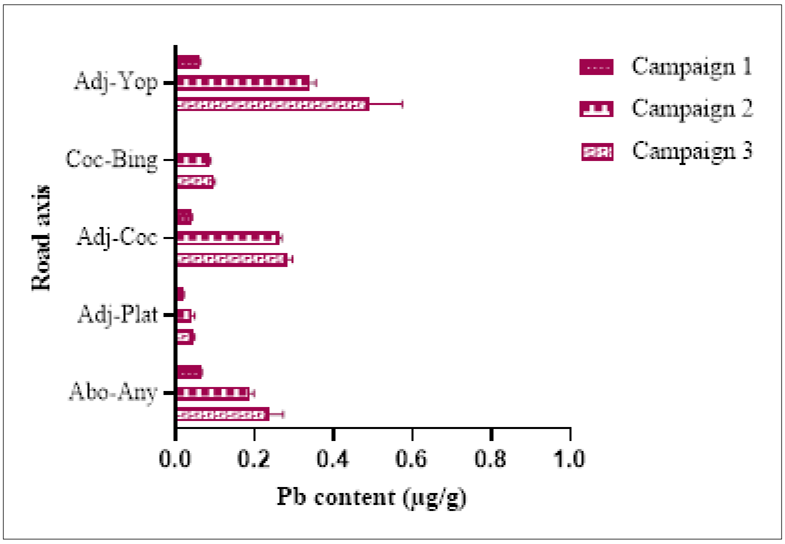

Figure 5 Content of lead on the different axis during the three campaigns

3.2. Mean bioaccumulation per MET on each road axis

The amounts of bioaccumulated METs were averaged over the study period for all roads included in the study. The results of this assessment are shown in Figure 6. This figure confirms the previous observations and highlights the strong predominance of zinc. The mean values for zinc vary between 0.440± 0.137 µg/g and 2.012± 0.541 µg/g. The mean values for lead [0.061 ± 0.013, 0.298 ± 0.022] remain very low compared to those for copper [0.178 ± 0.075, 0.386 ± 0.034].

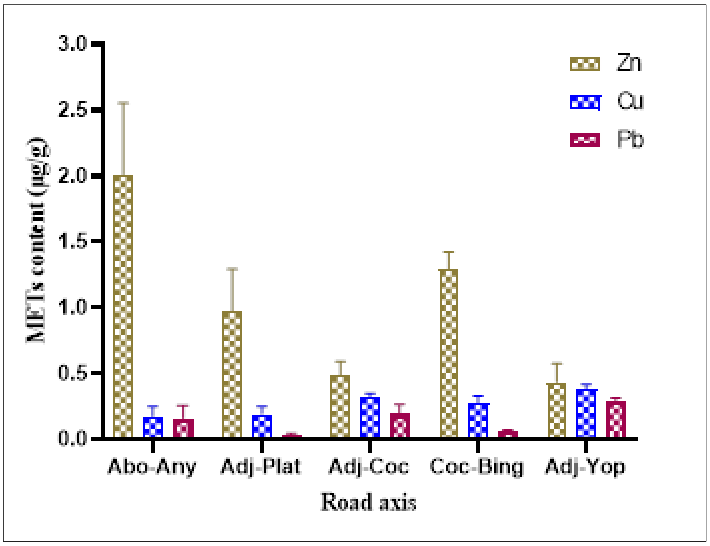

Figure 6 Average content of METs on the study roads

4. Discussion

In this study, the capacity of the plant species *Hibiscus tiliaceus rubra* to bioaccumulate trace metals was evaluated along different roads in the city of Abidjan. The control samples contained low levels of copper (Cu) and zinc (Zn), but virtually no lead (Pb) in the control leaves. The results of the different campaigns showed high levels of zinc, copper and lead in the exposed leaves compared to the control leaves. The presence of Cu and Zn in the control samples could be partly explained by the nutritive nature of these metals for the plants. The absence of lead in the controls is explained by its non-essential role in the normal nutritional process of the species. On the other hand, all the anomalies observed with Cu, Pb and Zn can be attributed to overexposure linked to the anthropogenic activities that generate them, or to probable contamination throughout the study area. This contamination may be the result of airborne particles or the deposition of contaminants on the ground. Given that the trends are observed throughout the study area, a source of soil contamination seems unlikely. Consequently, changes in MET levels could be mainly related to airborne particles. The density and direction of dispersion of this pollutant mass in the air depends on the meteorological conditions, in particular the prevailing winds, which transport and disperse the particles. The movement of these particles is also linked to their size and physico-chemical composition. The trends observed for lead are linked to car traffic. Car tyres contain lead and their abrasion is likely to release this metal into the environment. Lead may also come from diesel engine exhaust, which is a complex mixture of gas phase compounds and solid particles. According to Hong et al [28], there are several types of METs, including lead, in exhaust gases. The high levels of lead found along the Adjamé-Cocody axis can be attributed to activities using cement in construction. On the Adjamé-Yopougon axis, the presence of lead may be due to the strong presence of industrial activities releasing particles that may contain lead through incineration chimneys. In addition, illegal lead-generating activities may be suspected.

Safari et al [29] have also shown that tree leaves are good biological matrices for monitoring atmospheric metals in a gas and petrochemical area. The results of our study are in the same order of µg/g, but lower than those of Atta ur rehman et al [30] who investigated the accumulation of heavy metals in dust and leaves of *Conocarpus erectus* in urban areas. These authors also found significant levels of copper, and zinc and highlighted the presence of lead, cadmium and nickel associated with road traffic in the city of Karachi.

5. Conclusion

This study demonstrated the effectiveness of the woody species Hibiscus tiliaceus rubra as a biomonitor for TMEs in the environment of the city of Abidjan. The levels of TMEs bioaccumulated in the leaves of this species vary according to the roads along which the trees are located. This species has demonstrated its ability to bioaccumulate TMEs in its leaves over a period of three (3) months. The results showed that the Adjamé-Cocody and Adjamé-Yopougon roads had the highest lead depositions. The Adjamé-Plateau road is the least contaminated.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] R. M. Stapleton, Pollution A to Z, volume 1: A-L, Macmillan. New York, United State of America, 2004.

[2] S. K. Purushothaman, J. Selvam, and V. Muthunarayanan, “Ambient indoor air pollution and its consecutive effect on environment materials and health,” Mater. Today, Proc., pp. 1–5, 2020, doi: 10.1016/j.matpr.2020.05.483.

[3] C. Elichegaray, S. Bouallala, A. Maitre, and M. Ba, “État et évolution de la pollution atmosphérique,” Rev. Mal. Respir., vol. 26, no. 2, pp. 191–206, Feb. 2009, doi: 10.1016/S0761-8425(09)71596-7.

[4] A. A. E. Ahouré and A. P. Tano, Politique économique et développement : bilan diagnostic de l’industrie ivoirienne. Abidjan, Côte d’Ivoire, 2009, www.capec-ci.org/website/docs/publications/PED/PEDN__03.pdf.

[5] N'Guessan Hassy Joseph Kablan, « L'invasion des véhicules d'occasion en transit par le port d’Abidjan: le dynamisme ambivalent d'une activité en plein essor », Les Cahiers d'Outre-Mer, 251 | 2010, p365-390. DOI: https://doi.org/10.4000/com.6044

[6] Y. Zoungranan, L. Ekou, T. Ekou, D. Fane and K.K. Dobi-Brice,“Accumulation of Polycyclic Aromatic Hydrocarbons from transplanted lichens Parmotrema dilatatum in the city of Abidjan (Ivory Cost),”Australian Journal of Basic and Applied Sciences ; vol. 12, no. 6, pp 12-16, 2018

[7] Y. Zoungranan, “Lichen Comme Bioindicateur de la Qualité de l’air de la Ville d’Abidjan en Éléments Traces Métalliques,” Eur. J. Sci. Res., vol. 148, no. 4, pp. 501–511, 2018.

[8] R. M. Stapleton, Pollution A to Z, volume 2: L-Z, Macmillan. New York, United State of America, 2004.

[9] K. A. M. Alsaleh, H. Meuser, A. R. A. Usman, M. I. Al-Wabel, and A. S. Al-Farraj, “A comparison of two digestion methods for assessing heavy metals level in urban soils influenced by mining and industrial activities,” J. Environ. Manage., vol. 206, pp. 731–739, Jan. 2018, doi: 10.1016/J.JENVMAN.2017.11.026.

[10] J. L. Parrott, A. J. Bartlett, and V. K. Balakrishnan, “Chronic toxicity of azo and anthracenedione dyes to embryo-larval fathead minnow,” Environ. Pollut., vol. 210, pp. 40–47, Mar. 2016, doi: 10.1016/J.ENVPOL.2015.11.037.

[11] D. Fernández-Calviño et al., “Heavy metals fractionation and desorption in pine bark amended mine soils,” J. Environ. Manage., vol. 192, pp. 79–88, May 2017, doi: 10.1016/J.JENVMAN.2017.01.042.

[12] F. Ugolini, R. Tognetti, A. Raschi, and L. Bacci, “Quercus ilex L. as bioaccumulator for heavy metals in urban areas: Effectiveness of leaf washing with distilled water and considerations on the trees distance from traffic,” Urban For. Urban Green., vol. 12, no. 4, pp. 576–584, Jan. 2013, doi: 10.1016/J.UFUG.2013.05.007.

[13] S. Norouzi, H. Khademi, A. F. Cano, and J. A. Acosta, “Biomagnetic monitoring of heavy metals contamination in deposited atmospheric dust, a case study from Isfahan, Iran,” J. Environ. Manage., vol. 173, pp. 55–64, May 2016, doi: 10.1016/J.JENVMAN.2016.02.035.

[14] C. Van Haluwyn, D. Cuny, and J. P. Garrec, “Définitions, concepts et enjeux généraux de la biosurveillance de la qualité de l’air,” in iBiosurveillance de la pollution atmosphérique, A. Blanchet, Ed. Paris, France: Pollution atmosphèrique, 2011.

[15] R. Merlen, “La biosurveillance : outil de surveillance de l’impact sur l’environnement des émissions atmosphériques industrielles et d’évaluation des risques sanitaires,” Pollut. atmosphérique, vol. 226, pp. 1–12, 2015.

[16] A. Semadi, “Une méthode biologique pour la détection de la pollution globale dans la région d’ Annaba (Algérie) A biological method for detection of global pollution in Annaba area (Algeria),” vol. 1995, no. 1926, 1995.

[17] G. Matin, N. Kargar, and H. B. Buyukisik, “Bio-monitoring of cadmium, lead, arsenic and mercury in industrial districts of Izmir, Turkey by using honey bees, propolis and pine tree leaves,” Ecol. Eng., vol. 90, pp. 331–335, May 2016, doi: 10.1016/J.ECOLENG.2016.01.035.

[18] Y. Song, B. A. Maher, F. Li, X. Wang, X. Sun, and H. Zhang, “Particulate matter deposited on leaf of five evergreen species in Beijing, China: Source identification and size distribution,” Atmos. Environ., vol. 105, pp. 53–60, Mar. 2015, doi: 10.1016/J.ATMOSENV.2015.01.032.

[19] R. E. Craig and A. J. T. Lex, “Hibiscus tiliaceus (beach hibiscus),” Species Profiles Pacific Isl. Agrofor., vol. 1.2, no. April, pp. 1–14, 2006.

[20] R. M. Rosa et al., “Protective effects of Hibiscus tiliaceus L. methanolic extract to V79 cells against cytotoxicity and genotoxicity induced by hydrogen peroxide and tert-butyl-hydroperoxide,” Toxicol. Vitr., vol. 21, no. 8, pp. 1442–1452, 2007, doi: 10.1016/j.tiv.2007.06.004.

[21] T. Youssef, “Stomatal, biochemical and morphological factors limiting photosynthetic gas exchange in the mangrove associate Hibiscus tiliaceus under saline and arid environment,” Aquat. Bot., vol. 87, no. 4, pp. 292–298, 2007, doi: 10.1016/j.aquabot.2007.07.001.

[22] S. G. Jian, T. Tang, Y. Zhong, and S. H. Shi, “Conservation genetics of Heritiera littoralis (Sterculiaceae), a threatened mangrove in China, based on AFLP and ISSR markers,” Biochem. Syst. Ecol., vol. 38, no. 5, pp. 924–930, 2010, doi: 10.1016/j.bse.2010.09.016.

[23] L. Braglia, S. Bruna, S. Lanteri, A. Mercuri, and E. Portis, “Scientia Horticulturae An AFLP-based assessment of the genetic diversity within Hibiscus rosa-sinensis and its place within the Hibiscus genus complex,” vol. 123, pp. 372–378, 2010, doi: 10.1016/j.scienta.2009.10.003.

[24] G. Rajeswari, B. Priyanka, R. E. Amrutha, C. Rajaram, R. S. Kanhere, and S. Nelson Kumar, “Hibiscus tiliaceus: A possible immunomodulatory agent,” J. Pharm. Res., vol. 6, no. 7, pp. 742–747, 2013, doi: 10.1016/j.jopr.2013.05.023.

[25] C. L. Cheng et al., “Tetracyclic triterpenoids isolated from semi-mangrove plant Hibiscus tiliaceus,” Chinese Chem. Lett., vol. 24, no. 12, pp. 1080–1082, 2013, doi: 10.1016/j.cclet.2013.07.011.

[26] C. Liu et al., “A New Concept on Quality Marker for Quality Assessment and Process Control of Chinese Medicines,” Chinese Herb. Med., vol. 9, no. 1, pp. 3–13, 2017, doi: 10.1016/s1674-6384(17)60070-4.

[27] Z. Z. Wang, J. Li, X. L. Tang, and G. Q. Li, “Triterpenes and Steroids from Semi-mangrove Plant Hibiscus tiliaceus,” Chin. J. Nat. Med., vol. 9, no. 3, pp. 190–192, 2011, doi: 10.3724/SP.J.1009.2011.00190.

[28] N. Hong, P. Zhu, A. Liu, X. Zhao, and Y. Guan, "Using an innovative flag element ratio approach to tracking potential sources of heavy metals on urban road surfaces," Environ. Pollut., vol. 243, pp. 410–417, Dec. 2018, doi: 10.1016/J.ENVPOL.2018.08.098.

[29] M. Safari, B. Ramavandi, A. M. Sanati, G. A. Sorial, S. Hashemi, and S. Tahmasebi, "Potential of trees leaf/ bark to control atmospheric metals in a gas and petrochemical zone," J. Environ. Manage., vol. 222, no. May, pp. 12–20, 2018, doi: 10.1016/j.jenvman.2018.05.026.

[30] A. ur Rehman, K. Yasmeen, F. Islam, S.A. Anees, A. Tariq, M. Zubair, M. Bilal, I.U. Rahman, S.U. Rahman and W.A. Hatamleh. 2023. "Assessment of heavy metal accumulation in dust and leaves of Conocarpus erectus in urban areas: Implications for phytoremediation", Physics and Chemistry of the Earth, Parts A/B/C 132: 103481. https://doi.org/10.1016/j.pce.2023.103481.