Pollution, 7(1): 197-204, Winter 2021 *Research Paper*
DOI: 10.22059/poll.2020.306742.855
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Chronological Study of Metallic Pollution Using Tree Rings at Tema Industrial Area

Edusei, G.[1*], Tandoh, J. B.[2], Edziah, R.[1] Gyampo, O.[2] and Ahiamadjie, H.[2]

1. Department of Physics, University of Cape Coast, University Post Office, Cape Coast, Ghana

2. Ghana Atomic Energy Commission (GAEC), P.O. Box LG 80, Legon-Accra, Ghana

Received: 22.07.2020 Revised: 24.10.2020 Accepted: 21.11.2020

ABSTRACT: Tree rings have been used to reconstruct past climates as well as to assess the effects of recent climatic and environmental changes on tree growth. Industrial emission is one of the major sources of pollutants in the atmosphere. This study determined heavy metals pollution chronologies from industrial emissions in the atmosphere of the Tema industrial area of Ghana using tree-rings as bio-indicators. Swietenia mahagoni (Mahogany) tree was bored and the rings counted and age determined to be 50 years spanning from 1968 to 2018. Tree growth rates were calculated through ring width measurements and related to annual precipitation data spanning over the sampling period. It was observed that wet seasons correlate with high growth rates of trees while low precipitation seasons correspond to low or no growth rate of trees. Energy Dispersive X-ray fluorescence (EDXRF) was used to investigate the presence and concentration of the four heavy metals (Cu, Zn, Fe and Pb). Concentration of Cu, Zn, Fe and Pb ranged from (1.92—6.70 mg/kg), (5.37 – 13.9 mg/kg), (0.10 – 0.36 mg/kg) and (12.13—90.13 mg/kg), respectively. Surprisingly, an increasing trend in concentration was observed for Zn and Cu with levels higher than the WHO guideline for heavy metals in the plant.

Keywords: Growth rings, Metal concentration, Industrial emission.

INTRODUCTION

In an urban environment, heavy metal pollutants are released from many different anthropogenic sources such as vehicles, industries, building construction or renovation, waste incineration, agriculture (fertilizers, pesticides, etc.) (Wajid et al., 2008; Popescu, 2011; Md-Tanvir et al., 2017). Industrial activities over the past decades have increased as a result of world economic growth and improved human welfare (Siyan et al., 2015; Cigu et al., 2019). Consequently, the rise of industrial activities causes high levels of pollutant emission which impact negatively on the environment (Oliva & Espinoza, 2007; Lee et al., 2010).

With the growth of industries, one can envisage high pollution levels beyond the already existing levels of which little efforts are being made towards its mitigation. A great number of the manufacturing industries are located in Tema near Accra and more than 90% of the country's industries are in the Southern part of the country (Ackah et al., 2016). Numerous epidemiological studies have documented that current day levels of

[*] Corresponding Author, Email: edusei22@yahoo.com

heavy metals are associated with adverse health effects, including increased risks of morbidity and mortality, mainly due to respiratory and cardio-vascular diseases (Pope & Dockery, 2006; Pope et al., 2002).

Most air pollution studies in Ghana are based on atmospheric aerosols collected on particulate matter filters (Aboh et al., 2012; Benjamin & Ayatulai-Abdul, 2018). This is an active method that gives an idea of trace-element atmospheric pollution only during the sampling time (Kathie et al, 2010). The measurements require sophisticated technical equipment which are generally expensive. In Ghana, it is difficult to use air samplers in remote areas due to lack of electricity. The usefulness of bio-indicators such as mosses, tree rings and lichens in determining trace- and heavy metal concentrations in different geographical areas has been discussed and demonstrated in several studies (Markert, 2003; Ng et al., 2006; Pdamo et al., 2003). Mosses and lichens are used because they readily reflect local changes in heavy-metal deposition and are also better accumulation indicators (Palmieri et al, 2016). A disadvantage of using mosses and lichens as passive samplers is that their growth range is limited. (Szczepaniak & Biziuk, 2003). A number of studies have shown the ability of trees to take up and incorporate pollutants into their annual growth rings (Nabais et al., 2014; Speer, 2010). Indeed, tree-rings have been used to provide annual records of pollution over decades, tracing pollutants on a spatial and temporal scales in relation to their sources (Cocozza et al., 2016; Danek et al., 2015; Odabasi et al., 2015). Our study focused on emissions from industries, which are the most significant and widely recognized sources of pollutant in the atmosphere. Specifically, the study was interested in industrial emission chronology recorded in tree rings for the past fifty (50) years at the Tema industrial area, in the Greater Accra Region of Ghana. Therefore, concentrations of heavy metals in tree rings were examined to understand heavy metals pollution variations and growth rates of trees in relation to rainfall patterns around the sampling points as detailed in an earlier study (Edusei et al., 2020) which shows that growth rates are higher in wet seasons than in dry seasons.

MATERIAL AND METHODS

Samples analyzed for this study were taken from Tema industrial area in the Greater Accra Region of Ghana. Tema industrial area is located 25 kilometers (16 miles) east of the capital city Accra and is located on this coordinate (5° 40′ 0″ N, 0° 0′ 0″ E). The roadside vegetation in the study area is dominated by Azadirachta Indica (Neem tree) and Swietenia mahagoni (Mahogany tree). The area is well suited for the study of pollution effects because of the persistent industrial and vehicular emissions along the main road. Figure 1, shows a map of the sampling site, with sampling locations indicated in red circles along the main road.

In June 2018, a Swietenia mahagoni (mahogany) tree, which is located at about one meter (1 m) from Nestle Ghana Limited and Tema Oil Refinery road was bored. The choice of this tree species was dependent on its ability to produce annual growth rings which is a prerequisite for trees being used as proxies.

A sharpened increment borer was used to extract cores from each stem. The resulting core from the tree, as shown in Figure 2, was removed using the extractor. The extracted core was labelled with a specific ID and the procedure was repeated on the opposite side of the stem. The samples were then stored in paper tubes to prevent any damage. Finally, the cores were mounted on wooden support beams and air dried for one week under controlled conditions.

After the cores and cross sections were electronically scanned, visual dating and cross dating were done. From the tree ring counting analysis performed, 50 annual growth rings were counted. Since the tree was logged in 2018, the age of the tree could be estimated by subtracting 50 from 2018, which gives 1968 as the birth year of the tree as indicated in Figure 3. The growth width was estimated using image J software.

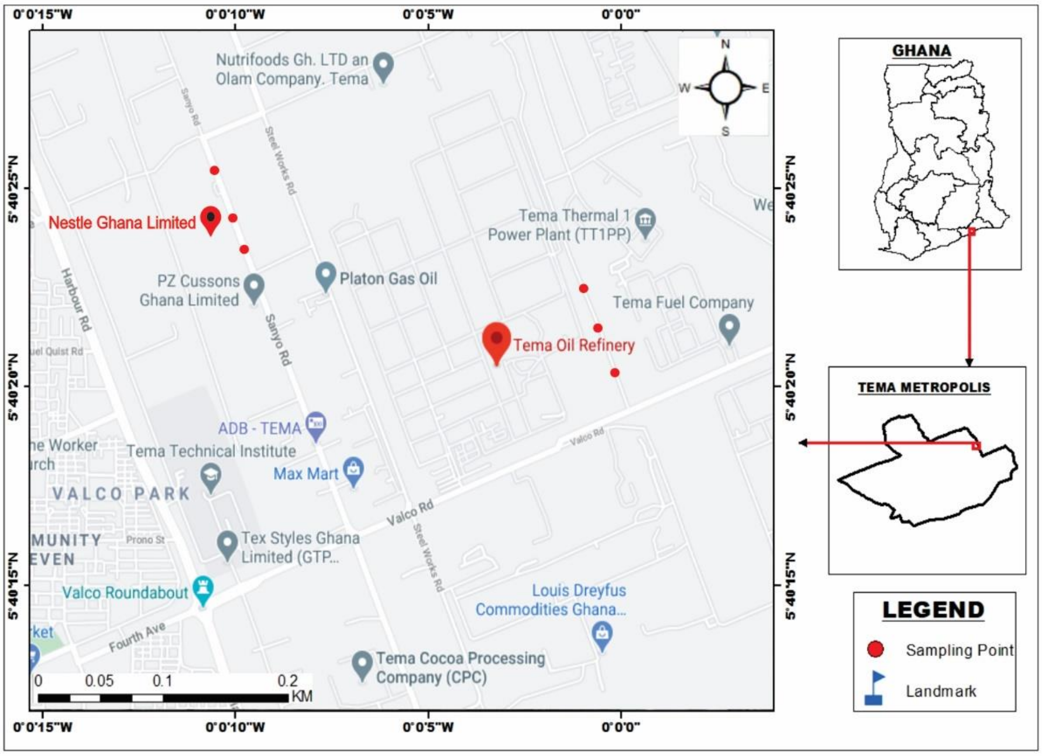

Fig. 1. Map showing sampling sites at Tema industrial area (sampling point are shown in red circles along the road

Fig. 2. Radial core of Swietenia mahogani obtained using increment tree borer.

Fig. 3. Photograph of radial core showing the pith (year the tree was born, 1968) and the bark (year the tree was logged, 2018). The age of the tree is estimated to be 50 years.

All the instruments passed the quality control/assurance tests that were carried out. The quality control/assurance procedure apply were core samples were collected at the breast height level to obtain the intrinsic properties in standing tree, radial line of the tree was bore to the pith, extracted cores were placed in precleared containers and transported to the laboratories, duplicate core samples were taken from the same tree approximately 1inches below the first core, borer was sharpened and cleaned before coring the tree and time accuracy.

Annual rings from the radial core were analyzed for heavy metal composition using Energy Dispersive X-ray Fluorescence Analysis (EDXRF).

RESULTS AND DISCUSSION

Tree ring width averaged for a period of five years (1968-2018) is shown in figure 4. Based on the results illustrated in figure 4, one can observe a consistent decrease in the growth of the tree from 1979 to 1994 which could be attributed to harsh environmental conditions such as drought, a typical growth inhibitor. After which there was a sudden sharp increase of growth from 1999 to 2009. The recorded average growth of 10.31 mm of the tree which was the highest life-time growth recorded for tree growth. Soon after this growth, there was a decline till 2018 when the tree was bored. This decline in growth could only be attributed to harsh seasonal variations or heavy metal pollution from industrial emission.

From Figure 4, some years recorded very high growth while others experienced sudden steep dip in growth. Tree growth rings were compared with annual wet and dry events recorded by the Ghana Meteorological Agency, Tema. Figure 4 is compared with precipitation levels (see Table 1) with levels above 60 mm and below classified as wet and dry, respectively. The years 1969, 1974, 1979, 1984 and 1989 recorded very high growth, which could be attributed to conducive environmental conditions such as enough rainfall during those years.

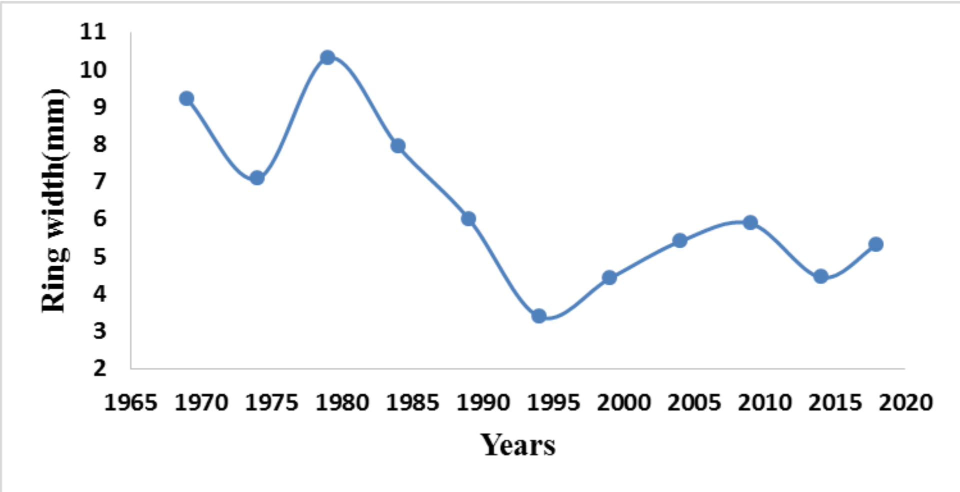

Fig. 4. A plot showing tree ring widths averaged over five-year period (1968-2018)

Table 1. Classification into wet and dry rainfall years at Tema (Ghana Meteorological Agency, 2019)

Year	Tema rainfall (mm)	Year	Tema rainfall (mm)
1969	74.58(wet year)	1994	41.76(dry year)
1974	72.82(wet year)	1999	42.93(dry year)
1979	73.18(wet year)	2004	33.92(dry year)
1984	78.44(wet year)	2009	52.76(dry year)
1989	61.32(wet year)	2014	37.34(dry year)
		2018	35.75(dry year)

From EDXRF analysis of the annual tree rings, four (4) elements: Cu, Zn, Fe and Pb were identified and quantified.

Copper (Cu): Figure 5 shows copper concentration in Swietenia mahagoni at Tema industrial area within the period 1968-2018. The average copper concentration as determined in the annual rings measured (1968 to 2018) ranged from 1.92 – 6.70 mg/kg, and these values are below the limits set by WHO for copper levels in plants (10mg/kg) (Zaigham et al., 2012). The graph shows the trend of copper concentration for 50 years from 1968-2018. From Figure 5, the concentration of copper started rising from 1968 to 2014 and this trend continued until 2018. The concentration of copper reached a peak value 6.70 mg/kg in 2017. The consistent increase in the levels of Cu can be attributed to the presence of an electrical copper wire production company on the stretch of road where the samples were taken. Cu pollution from vehicles has been linked to wear of brake lining (Vecchi et al. 2007).

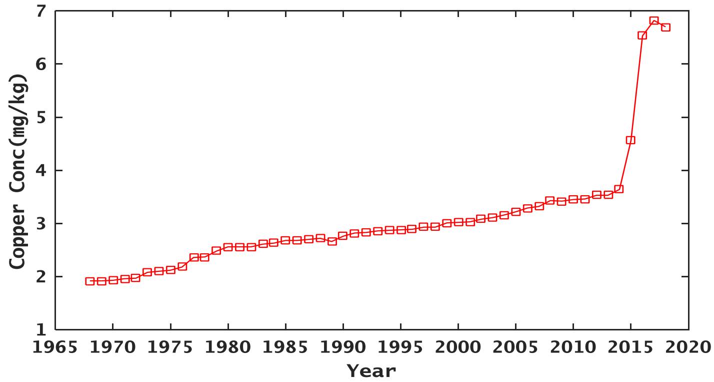

Fig. 5. Copper concentration in Swietenia mahagoni at Tema industrial area within the period 1968-2018.

Zinc (Zn) concentrations were also determined for annual rings sampled from the bored Swietenia mahagoni tree which spanned from 1968 to 2018 as shown in Figure 6. The graph shows the trend of zinc concentration for 50 years; zinc concentrations were determined to range between 5.37 – 13.9 mg/kg. The concentration increased from 1968 to 1976 and then decreased up to 1982 and later remained constant within the period 1985 to 1992. The concentration thereafter followed an increased trend from 1993 to 2005. The highest concentration of Zn was recorded in 2005 with a value of 13.9mg/kg. The zinc values recorded at the site were below the WHO's recommended maximum limit of zinc in plants which is 50 mg/kg (Afzal et al., 2011). In this study, observed concentrations of zinc at the industrial area can be attributed to wastes from metal manufacturing industries.

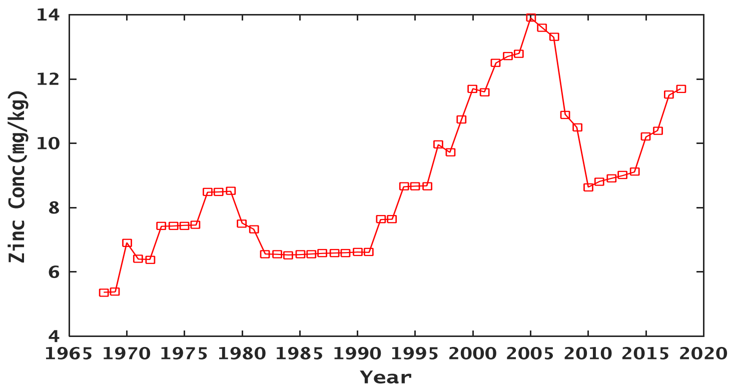

Fig. 6. Zinc concentration in Swietenia mahagoni at Tema industrial area within the period 1968-2018.

Iron (Fe): Figure 7 shows the trend of iron concentration for 50 years from 1968-2018. Based on the results illustrated in Figure 7, the concentration of iron fluctuated from 1968 to 1988 and then followed a decreased trend till 1993. There was a sharp increase in the concentration from 1994 to 1996, then followed abrupt variation from 1997 to 2018. The highest concentration value of 90.1 mg/kg was recorded in 1996. The WHO recommended level of iron in plants is 20 mg/kg (Afzal et al., 2011). Therefore, iron concentration values recorded at the Tema industrial area is above WHO recommended level and this can be credited to iron and steel industries and road dust (Atiemo et al., 2012). Iron (Fe) pollution from vehicles results from the wear-and-tear of brake pads and other automobile parts (Schauer, 2006).

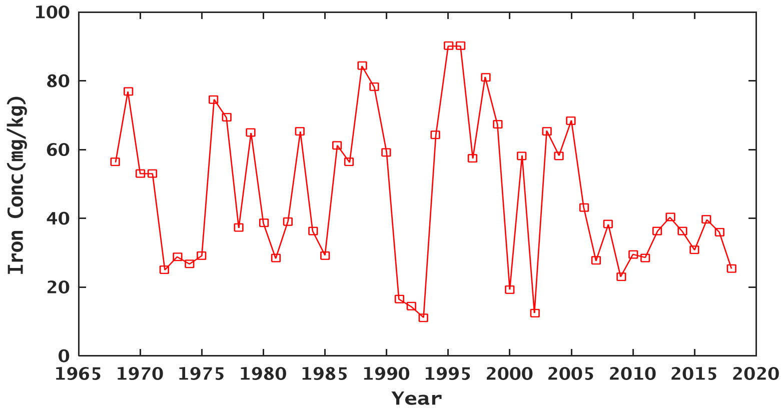

Fig. 7. Iron concentration in Swietenia mahagoni at Tema industrial area within the period 1968-2018.

Lead (Pb): The graph in Figure 8 shows the trend of Pb concentration for 50 years from 1968-2018. The Figure shows that the concentration of Pb fluctuated from 1968 to 2002 and then followed a decreased trend till 2018. The highest concentration value of 0.45 mg/kg was recorded in 1970. The maximum concentration limit of lead in plants, as recommended by WHO, is 2 mg/kg. Although Pb values were high in some years, the industries located at the sampling site do not manufacture or deal in Pb products. However, consistent decrease in the levels of lead (2004-2018) confirms a positive effect phase-out of the use of leaded fuel in automobiles.

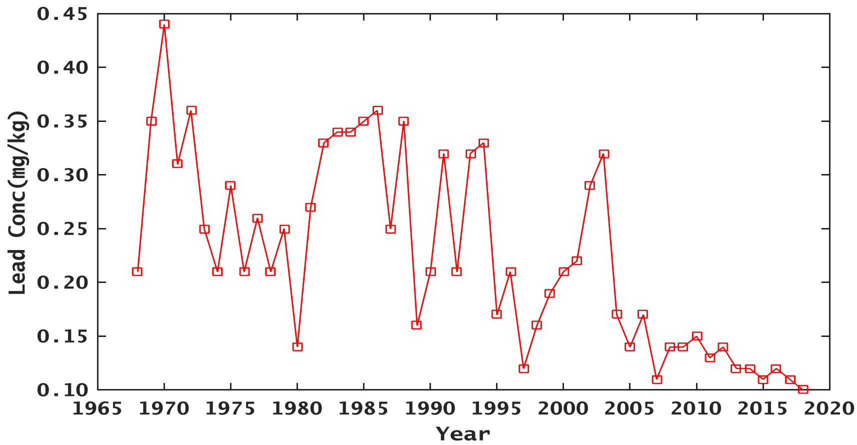

Fig. 8. Lead concentration in Swietenia mahagoni at Tema industrial area within the period 1968-2018.

CONCLUSION

Chronological studies of heavy metal concentration in the atmosphere using tree rings as bio indicators have been carried out at the Tema Industrial Area, Accra, Ghana. Concentrations of Zinc, Lead, Iron and Copper as recorded in tree rings over a period of 50 years were successfully measured using XRF technique. Sudden spike was observed in the Cu concentrations around 2015 which coincides with the siting of a copper production company. Anthropogenic sources contributed to the rise of all the elements measured, Zn, Pb, Cu and Fe. Over the past 50 years' activities like the increase in automobile and industrial activities have really cause an observable increasing trend in the concentrations of Zn, Pb, Cu and Fe. This study has confirmed the decreasing trend in Pb concentration from 2003 till 2017 when the samples were taken. High precipitation levels have been linked to high tree growth rates, which is reflected in the tree ring widths measured.

ACKNOWLEDGMENT

I extend my acknowledgment to Mr. Yaw Nsuo Brobbey and Mr. Kwame Opoku Mensah for their total support of this research work.

GRANT SUPPORT DETAILS

The present research has been financially supported by Ghana Education Trust Fund (GET Fund)

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Aboh**,** I. J. K., Ofosu, G. K., Hopke, P. K. and Bamford, S. A. (2012). Characterization of fine particulate sources at Ashaiman in Greater Accra, Ghana. Atmos. Pollut. Res. 3: 301-310.

Ackah, C., Adjasi, C. and Turkson, F. (2016). Scoping study on the evolution of industry in Ghana. https://www.brookings.edu/wp-content/uploads/2016/07

Afzal, S., Abdul, N., Nazeef, U. A., Muhammad, A., Muhammad, Z. and Muhammad S. K. (2011). Comparative study of heavy metals in oil and selected medicinal plants. Res. J. Chem. Environ. 7(4), 71-79.

Atiemo, G., Ofosu G. K. and Aboh, I. K. (2012). Levels and sources of heavy metal contamination in road dust in selected major highways of Accra, Ghana. X-Ray. Spectrom. 41(2)

Benjamin, A. and Ayatulai-Abdul, M. (2018). Assessment of Inhalable Particular Matter (PM) associated with a cement factory in Tema, Ghana. Am. J. Environ. Eng, 8(5), 167-173.

Cigu, E., Agheorghiesei, D. T. and Toader, E. (2019). Transport infrastructure development, public performance and long-run economic growth: a case study for the Eu-28 countries. Sustain, 11(1), 67

Cocozza, C., Ravera, S., Cherubini, P., Lombardi, F., Marchetti, M. and Tognetti, R. (2016). Integrated biomonitoring of airborne pollutants over space and time using tree rings, bark, leaves and epiphytic lichens. Urban Forestry and Urban Greening. 17: 177-191.

Danek, M., Bell, T. and Laroque, C. P. (2015). Some considerations in the reconstruction of lead levels using laser ablation: lessons from the design stage of dendrochemistry study, St. John's, Canada. Geochronometria. 42: 217-23.

Edusei, G., Tandoh, J. B., Edziah, R. and Gyampo, O. (2020). Chronological studies of traffic pollution using elemental analysis of tree rings: Case Study of Haatso-atomic Road. Pollut, 6(2): 377-386.

Kathie, L. D., Raphael, E., Allison, F. H. and Agyei-Mensah, S. (2010). Air pollution in Accra neighborhoods: Spatial, socio-economic and temporal patterns. Environ. Sci. Tech. 44(7), 2270-2276.

Lee, D. S., Pitari, G., Grewe, V., Gierens, K., Penner J. E., Petzold, A., Prather, M. J., Schumann, U., Bais, A., Berntsen, T. and Iachetti, D. (2010). In atmospheric environment transport impacts on atmosphere and climate: Aviation. Atmos. Environ. 44(37): 4678-4734.

Markert, B. A. (2003). Definitions, strategies and principles for bioindication/biomonitoring of the environment. J. Environ. 6: 3-39.

Md-Tanvir, H. M., Emadu, H., & Rajada, K. (2017). Heavy metal contamination in agricultural soil at DEPZA, Bangladesh. Environ. Ecol. Res. 5(7): 510-516.

Nabais, C., Campelo, F., Vieira, J. and Cherubini, P. (2014). Climatic signals of tree-ring width and intra-annual density fluctuations in Pinus pinaster and Pinus pinea along a latitudinal gradient in Portugal. Int. J. For. Res. 87: 598 –605

Ng, O. H., B. C. and Obbard, J. P. (2006). Lichens as bioindicators of atmospheric heavy metal pollution in Singapore. Enivron. Monit. Assess. 123: 63-74.

Odabasi, M., Ozgunerge Falay, E., Tuna, G., Altiok, H., Kara, M., Dumanoglu, Y., Bayram, A., Tolunay, D. and Elbir, T. (2015). Biomonitoring the spatial and historical variations of persistent organic pollutants (POPs) in an industrial region. Environ. Sci. Tech. 49: 2105-2114.

Oliva Rossini, S. and Espinosa Fernandez, J. A. (2007). Monitoring of heavy metals in topsoil, atmospheric particle and plant leaves to identify possible contamination sources. Elsevier. Microchem. J. 86(1): 131–139.

Palmieri, F., Neri, R., Benco, C. and Serracca, L. (2016). Lichens and moss as bioindicators and bioaccumulator in air pollution monitoring. Air pollution in formation system. J. Environ. 75: 1260.

Pdamo, P., Giordano, S., Vingiani, S. and Violante, P. (2003). Trace element accumulation by moss and lichen exposed in bags in the city of Naples (Italy). Environ. Pollut. 122: 91-103.

Pope, C. A., Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., Ito, K. and Thurston, G. D. (2002). Lung cancer, cardio-pulmonary mortality and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc. 287: 1132–1141.

Pope, C. A. and Dockery, D. W. (2006). Acute Health Effects of PM_{10} Pollution on Symptomatic and Asymptomatic Children. Am. J. Respir. Crit. Care Med. 145: 1123- 1128.

Popescu, C. G. (2011). Relation between vehicle traffic and heavy metals content from the particulate matters. Rom. Rep. Phys. 63(2): 471–482.

Schauer, J. J., Lough, G. C., Shafer, M. M., Christensen, W. F., Arndt, M. F., DeMinter, J. T. and Park, J. S. (2006). Characterization of metals emitted from motor vehicles. Res. Rep. Health. Eff. Inst.133: 1-76

Siyan, P., Eremiokhale, R. and Makwe, E. (2015). The impact of road transportation infrastructure on economic growth in Nigeria. Inter. J. mgt. comm. inno. 3(1): 673-680.

Speer, J. (2010). Fundamentals of tree-ring research. Prof. Geogr. 63(1): 150–151

Szczepaniak, K. and Biziuk, M. (2003). Aspect of the biomonitoring studies using mosses and lichen as indicators of metal pollution. Environ. Res. 93(3): 221-30.

Vecchi, R., Marcazzan, G. and Valli, G. (2007). A study on nighttime-daytime PM_{10} concentration and elemental composition in relation to atmospheric dispersion in the urban area of Milan. Atmos. Environ. 41: 2136–2144.

Wajid, R., Akif, Z., Nayyara, N. and Mohsan, N. (2008). Heavy metal pollution assessment in various industries of Pakistan. Environ. Geol. 55(2): 353–358.

Zaigham, H., Zubair, A., and Khalid U. K., Mazhar, I., Rizwan Ullah, K. and Jabar Zaman, K. K. (2012). Civic pollution and its effect on water quality of river Toi at District Kohat. Res. J. Environ. Earth Sci. 4(3): 334-339.