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Effect of Atmospheric Deposition of Pollutants on the Concentration of Trace Metals on Some Sun-Dried Food Items Dried at a Non-Vehicular Corridor in Ile-Ife Nigeria

Grace Olubumi Akinlade [1], Danjuma Dan-Adam Maza [1]*, Iyabo Oluremi Olabanji [2], Joshua Olufemi Ojo [1]
[1]Department of Physics and Engineering Physics, Obafemi Awolowo University, Ile-Ife, Nigeria
[2]Department of Chemistry, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract. The effect of atmospheric pollution on some sun-dried food items in Ile-Ife, Nigeria was investigated. Six farm produce: cassava (*Manihot esculenta*), plantain (*Musa x paradisiaca*), white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*), red cocoyam (*Xanthosoma sagittifolium*) and sweet potato (*Ipomoea batatas*) were exposed, for different hours (0 h, 8 h, 20 h, 32 h, 42 h), to the sun at a location far from vehicular activities. Exposed samples were digested and analyzed for Cu, Zn, Ni, Mn, Cd, and Pb using Atomic Absorption Spectroscopy (AAS). The concentration of Cu, in exposed samples, ranged from 1.40 ± 0.93 mg/kg in sweet potato (32 h exposure) to 12.96 ± 0.71 mg/kg in cocoyam (0 h exposure), while the concentration of Zn ranged from 2.65 ± 0.27 mg/kg in plantain (42 h exposure) to 21.86 ± 4.51 mg/kg in cocoyam (0 h exposure). On the other hand, the concentration of Mn ranged from 0.55 ± 0.12 mg/kg in plantain (42 h exposure) to 18.22 ± 2.14 mg/kg in sweet potato (0 h exposure). Furthermore, the concentration of Ni ranged from 0.10 ± 0.08 mg/kg in yellow yam (32 h exposure) to 2.90 ± 0.31 mg/kg in the plantain (32 h exposure). The concentration of Cd ranged from 0.6 ± 0.093 mg/kg in cassava (32 h exposure) to 1.0 ± 0.10 mg/kg in plantain (20 h exposure). In comparison, the concentration of Pb ranged from 0.3 ± 0.082 mg/kg in cassava (20 h exposure) to 0.8 ± 0.093 mg/kg in plantain (20 h exposure). The study observed that there was no particular pattern in the effect of atmospheric deposition of the pollutants, Cu, Zn, Ni, Mn, Cd, and Pb, on the concentration of these pollutants in the sun-dried farm products, for the different exposure hours. The study believed that the non-uniform pattern could result from differences in the concentrations of the pollutants in the atmosphere. It could also be a result of the different water retention abilities of the respective farm products, which may impact the absorption or evaporation of deposited pollutants on these farm products.

Keywords: atmospheric deposition, heavy metals, essential elements, concentration, sun-dried, farm products

Introduction

The farm products cassava (*Manihot esculenta*), plantain (*Musa x paradisiaca*) white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*), sweet potato (*Ipomoea batatas*), and cocoyam (*x sagittifolium),* are widely consumed in Nigeria as sources of carbohydrates and essential nutrients for human health. Furthermore, farm products have been

* Corresponding Author

shown to contain heavy metals: lead (Pb) and cadmium (Cd), as well as essential trace elements copper (Cu), zinc (Zn), manganese (Mn), and nickel (Ni) (Pilarczyk *et al.*, 2013; Corguinha *et al.*, 2015; Kumar & Seema, 2016; Malinidevi & Inbanila, 2016; Orisakwe *et al.*, 2017; Hitler *et al.*, 2018; Rai *et al.*, 2019; Motas *et al.*, 2021; Ahogle *et al.*, 2023). While the essential elements zinc, manganese, copper, and nickel are widely recognized for their nutritional and beneficial functions in the human body (Olivares & Uauy, 1996; Brown *et al.*, 2001; Soetan *et al.*, 2010; Bhowmik *et al.*, 2010; Temple & Masta, 2004; Devi *et al.*, 2014; Prashanth *et al.*, 2015; Kelkitli *et al.*, 2016; Karim, 2018; Fallah *et al.*, 2018; Vinha *et al.*, 2019), lead and cadmium have no known benefits to man, however, their adverse health effects on man are well documented (Godt *et al.*, 2006; Nordberg *et al.*, 2018; Satarug, 2018; Andjelkovic *et al.*, 2019).

Southwestern Nigeria produces large quantities of these farm products, but they cannot be stored for an extended period in their natural state, resulting in post-harvest losses. These products often need to be dried to be stored for a more extended period. In Nigeria, sun-drying, which is an ancient method of food processing and preservation (Mujumdar & Devahastin, 2012; Ada *et al.*, 2018), is still being used to process and preserve these farm products, particularly in rural areas, as it is affordable and less sophisticated than other methods. It is not unusual for farmers to spread these products along the highways for a few days, sometimes overnight, before being collected. The food items are thus subject to contamination from exposure to vehicular emissions, road dust, and even rodent infestation (Bolade, 2016). Sun-dried food products' safety and quality are affected by the quality of air passing over it. Pollutants such as heavy metals and trace elements are known to enter the atmosphere from natural and anthropogenic sources. Since atmospheric transportation has no boundary, these atmospheric pollutants are transported from place to place and may later deposit on sun-dried farm products due to gravity. Deposition of atmospheric pollutants on sun-dried farm products may lead to contamination of these products, which may have deleterious consequences on human health.

In Ile-Ife, where this investigation was conducted, October - March is a dry season with plentiful sunshine and little rainfall. As a result, farmers can sun dry their farm products without having to worry about the weather. The research efforts of Owoade and collaborators showed the air over Ile-Ife to be polluted (Owoade *et al.*, 2013). Particulate matter ranged from 99.5 $\mu g/m^3$ for $PM_{2.5}$ during the wet season to 303.6 $\mu g/m^3$ during the dry months while the coarse particulates ($PM_{2.5-10}$) ranged from 55 $\mu g/m^3$ during the wet months to 139.3 $\mu g/m^3$ during the dry months.

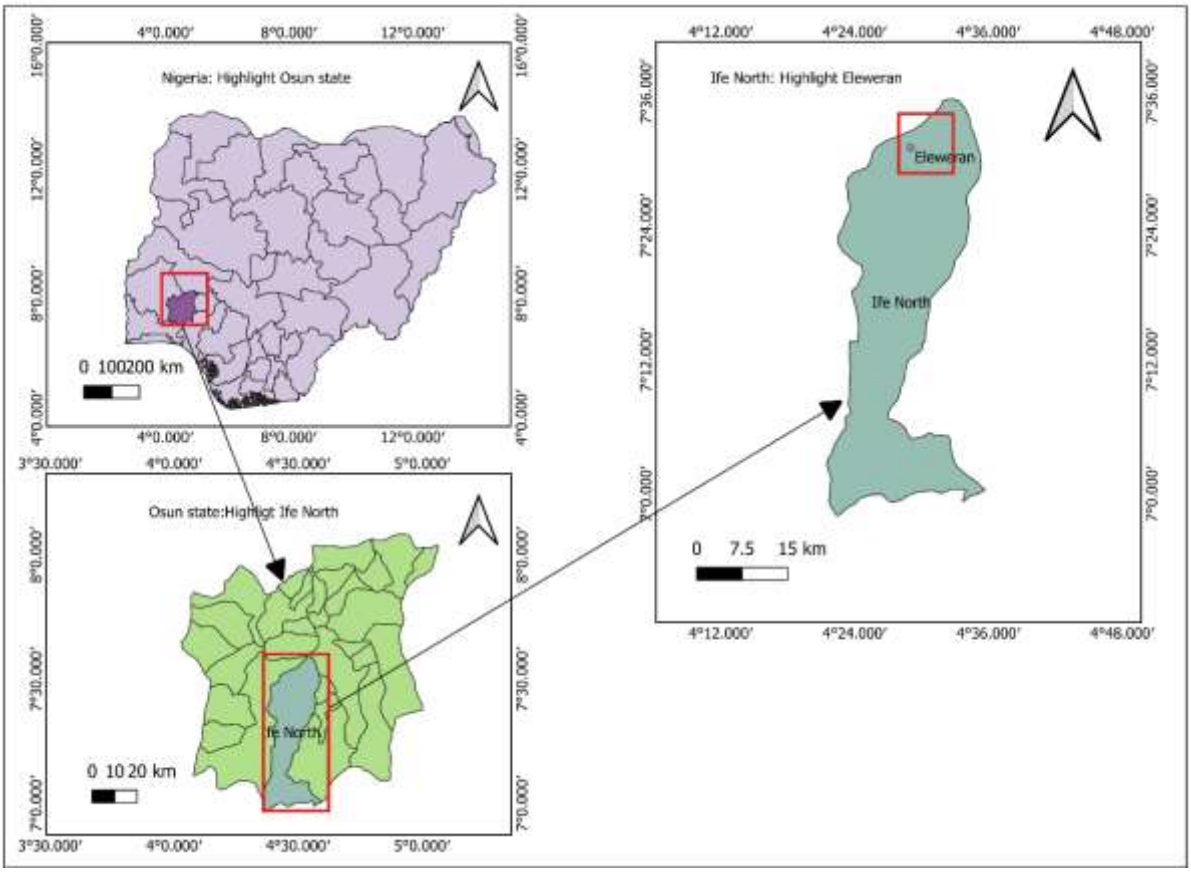
Previous studies on the metallic pollution of sun-dried food products have been carried out on food items dried along some major highways in Nigeria (Adebayo & Raphael, 2011; Bolade, 2016; Dibofori-Orji & Edori, 2015; Obanijesu & Olajide, 2009). To the best of our knowledge, the pollution effect of sun-drying on food items dried at non-vehicular corridors is yet to be investigated. This work, therefore, seeks to investigate the influence of atmospheric pollutants on the concentrations of trace metals contained in sun-dried food items which are not dried along the highways.

Materials and Methods

The Study Area

This investigation was carried out at Eleweran, a suburb of Ile-Ife in Ife North Local Government Area (LGA) (see Figure 1), Osun State, Southwest Nigeria, located at latitude 7° 31’ 0’’ (7.51667°) N and longitude 4° 28’59’’ (4.48333°) E, with an elevation of 261 m above

sea level. Two major seasons are defined over the region, namely; the wet season between April and October and the dry season between November and March (Odekunle, 2004; Eludoyin & Adelekan, 2012). The two seasons are brought about by the meridional movement of the inter-tropical discontinuity (ITD) line which is the separation between the dry and dust-laden North-East trade winds and the moist South-West trade winds. During the dry season, the ITD line may migrate south of the station bringing it under the influence of the dry dust-laden North-East trade winds. This period is locally known as harmattan. During this period, the atmosphere becomes turbid and dust of Saharan origin settles everywhere, reducing the air



quality over the region.

Figure 1: Study area Map (Designed using QGIS version 3.28.2)

Sampling and Drying

Cassava tubers were peeled, washed and soaked for 3 days until they became soft. Water was then squeezed from it with the aid of hydraulic press, which reduced the water content greatly so as to facilitate easy drying in the sun. Semi dried cassava paste was then spread on a clean tray and exposed to the sun. A part of it was set aside as control which was oven dried at temperature of 70° C for 72 hours. Samples were then collected after different hours of exposure (8 h, 20 h, 32 h, 42 h) and oven dried. Unripe plantain fingers, sweet potatoes' tubers, two different yam species, and cocoyam (*Musa x paradisiaca*, *Ipomoea batatas*, *Discorea rotundata*, *Discorea cayanesis* and, *x. sagittifolium*) were also harvested, peeled, sliced and spread in a clean tray for exposure. Exposed samples were collected after different hours representing different exposure hours (8 h, 20 h, 32 h, 42 h). The control had zero exposure hour in each case and all the samples were completely dried in the oven. All the farm products

were harvested from the same farm land. While Cassava and plantain were harvested and dried in February, 2018, sweet potatoes, yams and cocoyam were harvested and dried in February 2019.

Sample Preparation, Digestion and Analysis

The dried samples were ground into a fine powder with the aid of a mortar and pestle. The powdered samples were then well labelled, put in an air-tight container, and kept in a refrigerator pending the time of analysis. The samples were digested and analysed in two batches, at different times and in different laboratories. Batch 1 comprises sweet potato, yams, and cocoyam while batch 2 comprises cassava and plantain. For batch 1, 1 g of dried samples were carefully weighed into a Teflon beaker. Ten milliliters (10 ml) of super pure nitric acid (70 %) were carefully added. The beakers were covered with Pyrex and left-over night in a fume cupboard. They were then heated to near dryness. The heating was removed and allowed to cool and filtered. The filtrate was made up to mark in a 25 ml flask with distilled water. The concentrations of Cd, Ni, Mn, Pb, Zn, and Cu were determined using Flame atomic absorption spectrometry (FAAS) at the Department of Geology, Obafemi Awolowo University, Ile-Ife. International Atomic Energy Agency (IAEA) reference material "Hay-IAEA-V-10" was also digested along with the samples and analysed to validate the procedure. For batch 2 digestion, 0.5 g of the grounded samples were each weighed into a Teflon beaker. Twenty-five milliliters (25 ml) of freshly prepared aqua-regia (HCl: HNO3 (3:1)) was added. These were then each heated to near dryness, the heating was removed and allowed to cool, and 20 ml of distilled water was then carefully added and heated again for about 3-5 minutes, allowed to cool and filtered. The filtrate was made up to mark in a 25ml flask with deionized water. The concentrations of Cd, Pb, Ni, Mn, Zn, and Cu were then determined using a PG 990 Atomic Absorption Spectrometry (AAS), located at the Centre for Energy and Research Development (CERD), Obafemi Awolowo University, Ile-Ife.

Results and Discussion

Quality Assurance/Quality Control

The calibration equations are presented in Table 1. It shows that the absorbance correlated well with the concentration values of the reference material, with an average R^2 value of 0.988.

Table 1: Calibration equations for the AAS facilities

	Batch 1		**Batch 2**	
Element	Regression Equation	R^2 value	Regression Equation	R^2 value
Copper (Cu)	$y = 0.1318x + 0.1086$	0.9974	$y = 2.8058x - 0.0178$	0.9984
Zinc (Zn)	$y = 0.5226x + 0.0457$	0.9743	$y = 3.9953x - 0.0211$	0.9992
Manganese (Mn)	$y = 0.0969x + 0.0125$	0.9857	$y = 2.7224x - 0.0083$	0.9945
Nickel (Ni)	$y = 0.0833x + 0.0227$	0.9854	$y = 3.5669x - 0.0109$	0.9824
Cadmium (Cd)	$y = 0.2465x + 0.213$	0.9781	$y = 3.6561x - 0.0086$	0.9906
Lead (Pb)	$y = 0.0501x + 0.0075$	0.9797	$y = 5.75x - 0.0113$	0.9925

Effect of Atmospheric Deposition on the Elemental Concentration of Pollutants

The concentration of the pollutants, Cu, Zn, Mn, Ni, Cd, and Pb, for different exposure hours in the farm products investigated, are presented in Tables 2 and 3, and graphically as bar charts (Figures 2 to 9). The concentrations of Cd and Pb were determined in cassava and plantain only. The concentration of Cu ranged from 1.40 ± 0.93 mg/kg in sweet potato (32 h exposure) to 12.96 ± 0.71 mg/kg in cocoyam (0 h exposure), while the concentration of Zn ranged from 2.65 ± 0.27 mg/kg in plantain (42 h exposure) to 21.86 ± 4.51 mg/kg in cocoyam (0 h exposure). On the other hand, the concentration of Mn ranged from 0.55 ± 0.12 mg/kg in plantain (42 h exposure) to 18.22 ± 2.14 mg/kg in sweet potato (0 h exposure). Furthermore, the concentration of Ni ranged from 0.10 ± 0.08 mg/kg in yellow yam (32 h exposure) to 2.90 ± 0.31 mg/kg in plantain. In cassava and plantain (32 h exposure). The concentration of Cd ranged from 0.6 ± 0.093 mg/kg in cassava (32 h exposure) to 1.0 ± 0.10 mg/kg in plantain (20 h exposure), while the concentration of Pb ranged from 0.3 ± 0.082 mg/kg in cassava (20 h exposure) to 0.8 ± 0.093 mg/kg in plantain (20 h exposure).

It was observed that the effect of atmospheric deposition of pollutants, Cu, Zn, Mn, Ni, Cd, and Pb, on the concentration of these pollutants in the sun-dried farm products, for the different exposure hours, followed no particular pattern. For instance, the concentration of Cu in cassava, plantain, and yellow yam were found to have increased following 8 h and 20 h exposure which thereafter decreased following 32 h and 42 h exposure. The case was, however, different for sweet potato, cocoyam, and white yam. For sweet potato and cocoyam, there was a significant decrease in the concentration of Cu after 8 h of exposure, thereafter, the concentration of Cu was not significantly affected after 20 h, 32 h, and 42 h exposures, respectively.

Table 2: Elemental concentrations in farm products for different exposure hours

Farm produce	Exposure hours (h)	Cu	Zn	Mn	Ni
		Concentration (mg/kg)			
Cassava	0	4.15	3.4	1	1.55
	8	4.75	4.05	0.85	1.4
	20	4.8	3.3	1.1	0.95
	32	4.4	4.45	0.8	1.9
	42	3.9	4.35	1.15	1.55
Plantain	0	4.9	2.95	0.7	2.1
	8	6.5	3.15	0.85	2.55
	20	6.75	3.4	0.6	2.3
	32	5.7	3.25	0.8	2.9
	42	5.75	2.65	0.55	2.65
Sweet Potato	0	3.609746	6.249373	18.22421	0.200541
	8	1.451742	3.068682	16.49479	0.876051
	20	1.75035	3.913283	17.17844	0.45009
	32	1.401261	3.215394	15.31378	0.575518
	42	1.604332	3.810288	12.63411	0.65176

Cocoyam	0	12.96779	21.85713	7.349253	0.275911
	8	7.923771	13.47793	6.243731	0.626881
	20	8.76092	16.2918	5.221408	0.803294
	32	6.29704	10.03261	4.264927	0.878073
	42	6.474603	12.55019	4.592451	0.501907
White yam	0	6.100674	7.185522	0.893404	0.5
	8	4.95	6.1875	0.89	0.75
	20	5.163425	7.602266	0.89	0.626629
	32	5.854098	8.68608	0.89	0.350245
	42	5.649859	10.0919	0.828646	0.401768
Yellow yam	0	5.311153	10.99058	1.7	0.526105
	8	8.812895	8.129959	1.305614	0.326404
	20	9.096361	7.804378	2.04918	0.87465
	32	5.791215	6.074509	1.955475	0.100281
	42	5.208855	5.902534	1.402384	0.150255

Table 3: Concentrations of Cd and Pb in cassava and plantain

Farm produce	Exposure hours	Cd	Pb
		Concentration (mg/kg)	
Cassava	0	0.7	0.35
	8	0.65	0.45
	20	0.85	0.3
	32	0.6	0.5
	42	0.7	0.35
Plantain	0	0.95	0.65
	8	0.8	0.6
	20	1.0	0.8
	32	0.75	0.55
	42	0.9	0.65

The lack of any particular pattern was equally observed in the effect of atmospheric deposition on the concentration of Zn, Mn, Ni, Cd, and Pb in the exposed farm products investigated. With the exception of cassava and plantain, the concentration of Ni was observed to be generally low for all exposure hours. Furthermore, the effect of atmospheric deposition on the concentration of Ni was generally not significant for all exposure hours, and for all farm produce investigated, suggesting that Ni's concentration in the air over the study area was low. This non-uniform pattern could be a result of differences in the concentrations of the pollutants in the atmosphere. It could also be a result of the different water retention abilities of the respective farm products, which may either enhance or hamper the absorption or evaporation of deposited pollutants on these farm products.

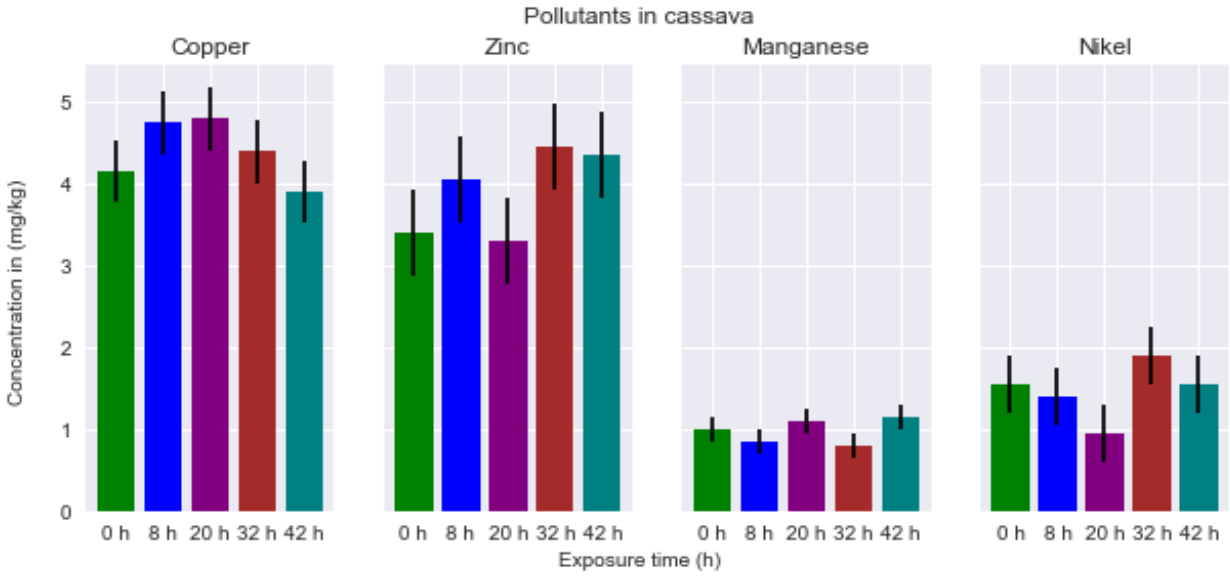


Figure 2: Concentration of Cu, Zn, Mn, and Ni in casava for different exposure time

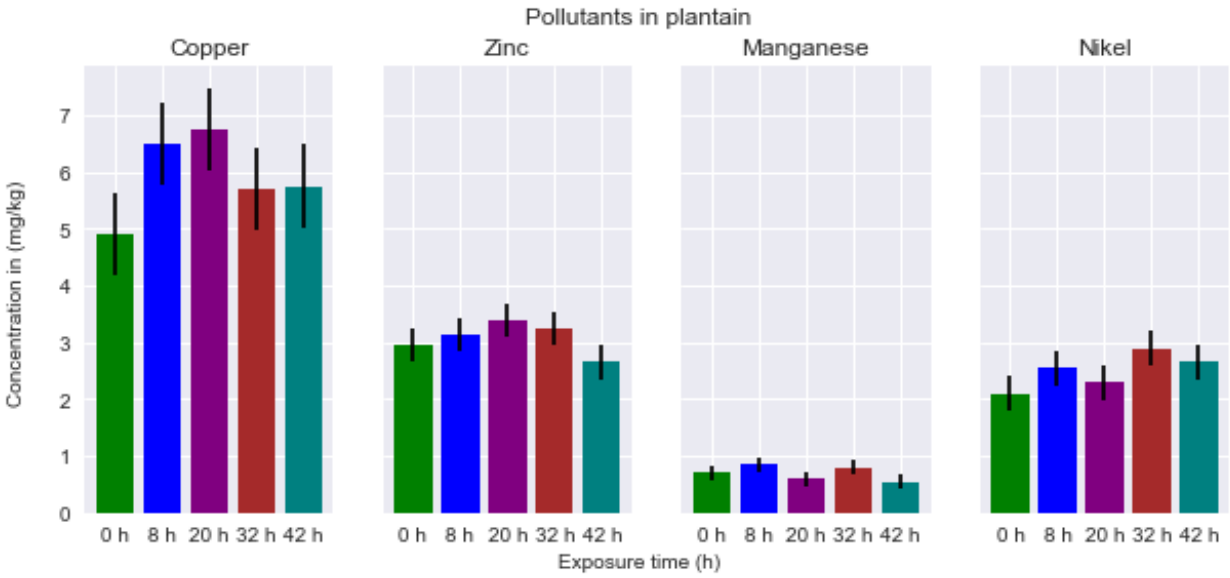


Figure 3: Concentration of Cu, Zn, Mn, and Ni in plantain for different exposure time

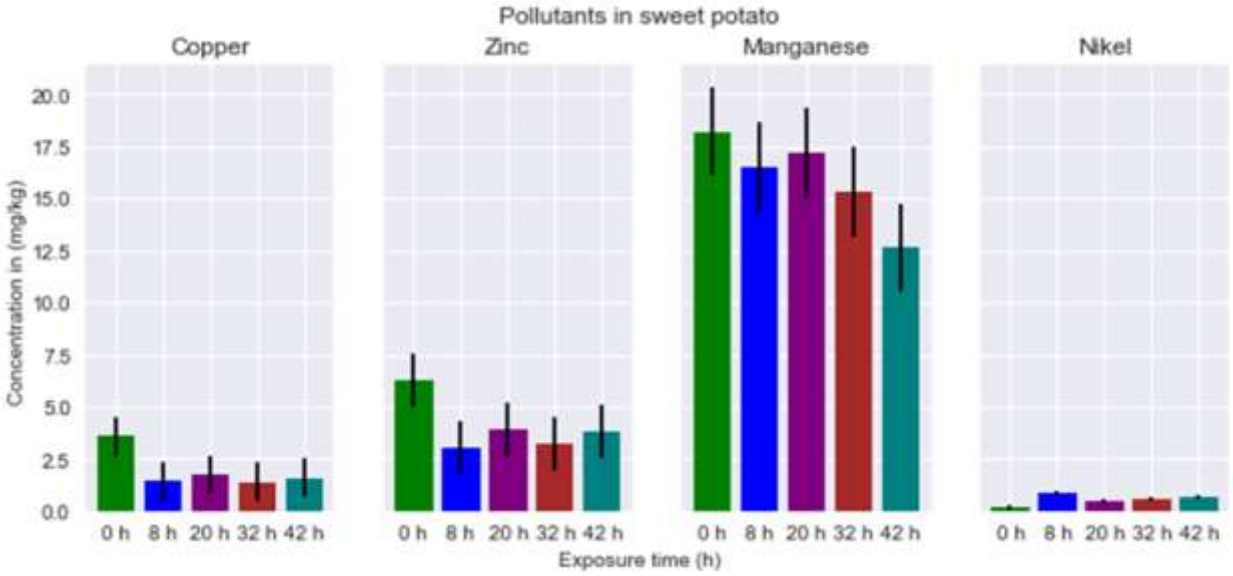


Figure 4: Concentration of Cu, Zn, Mn, and Ni in sweet potato for different exposure time

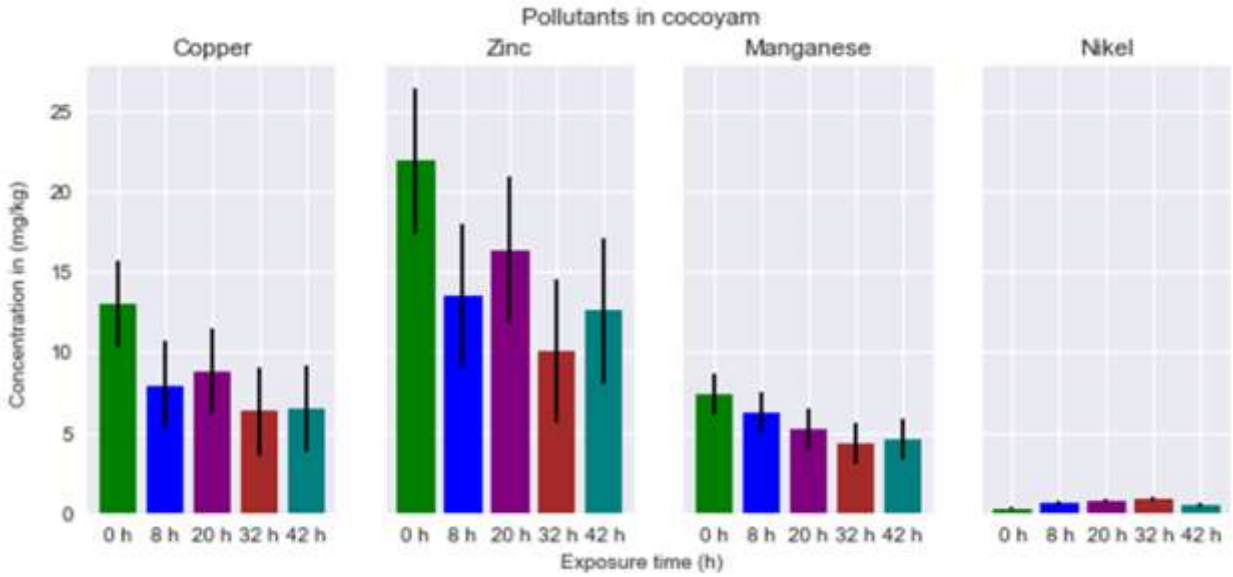


Figure 5: Concentration of Cu, Zn, Mn, and Ni in cocoyam for different exposure time

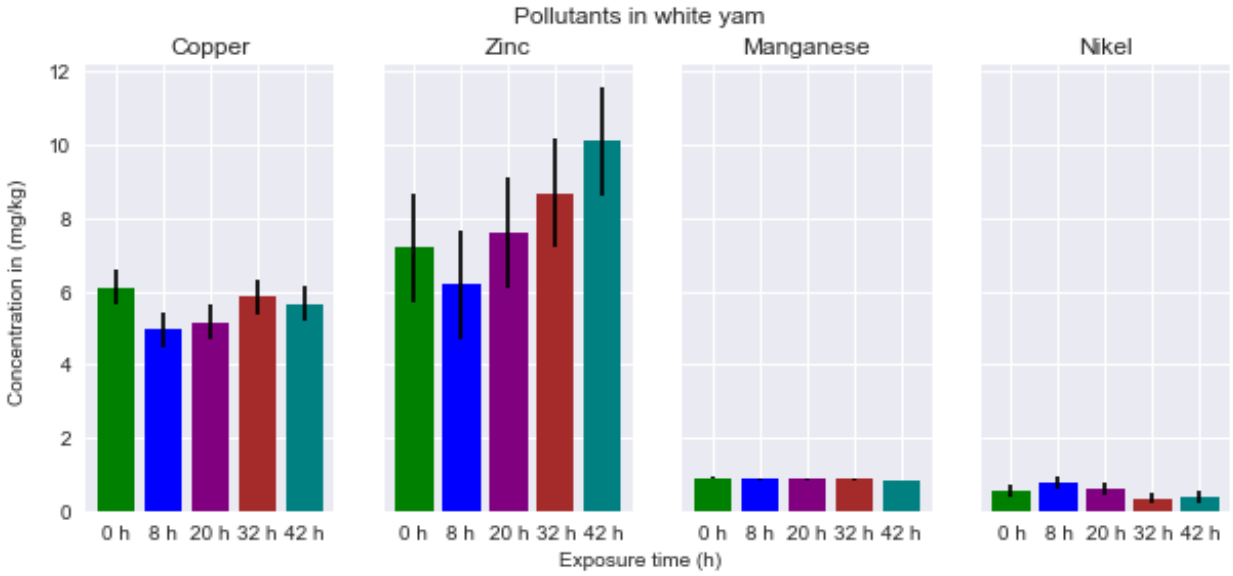


Figure 6: Concentration of Cu, Zn, Mn, and Ni in white yam for different exposure time

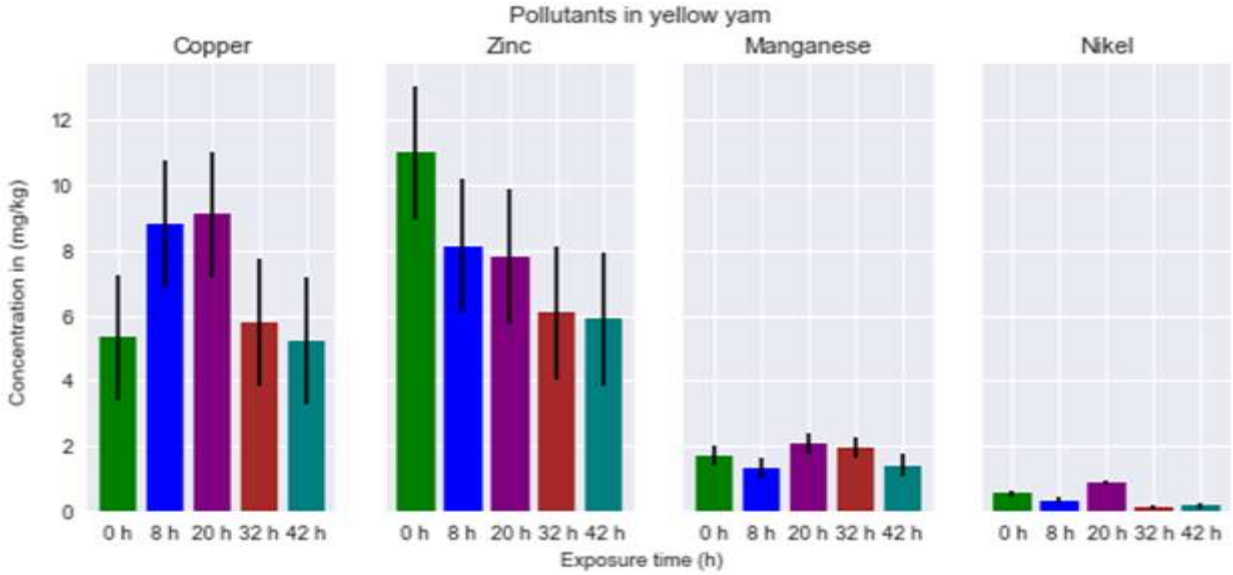


Figure 7: Concentration of Cu, Zn, Mn, and Ni in yellow yam for different exposure time

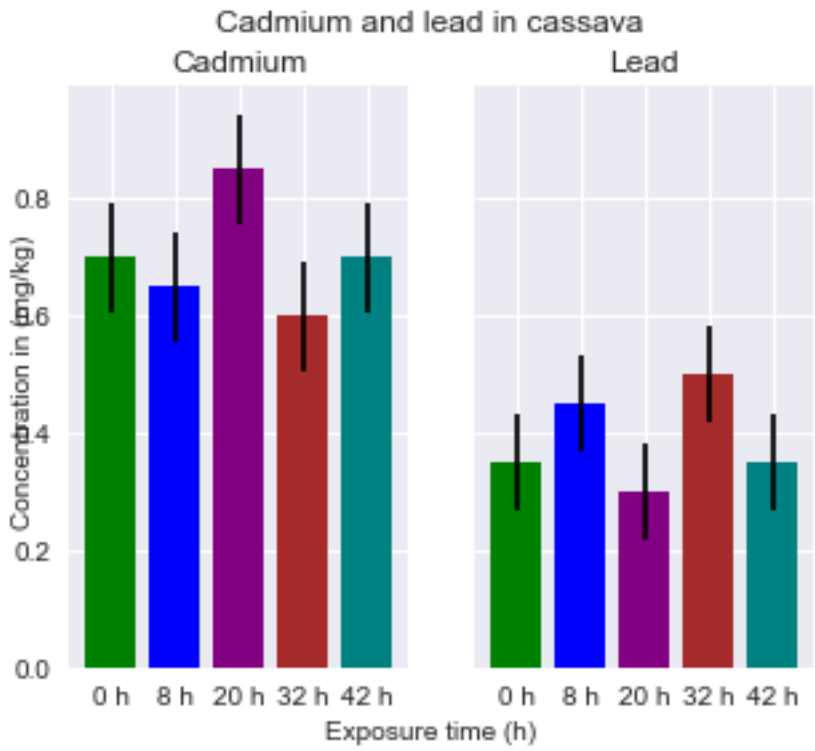


Figure 8: Concentration of Cd and Pb in casava for different exposure times

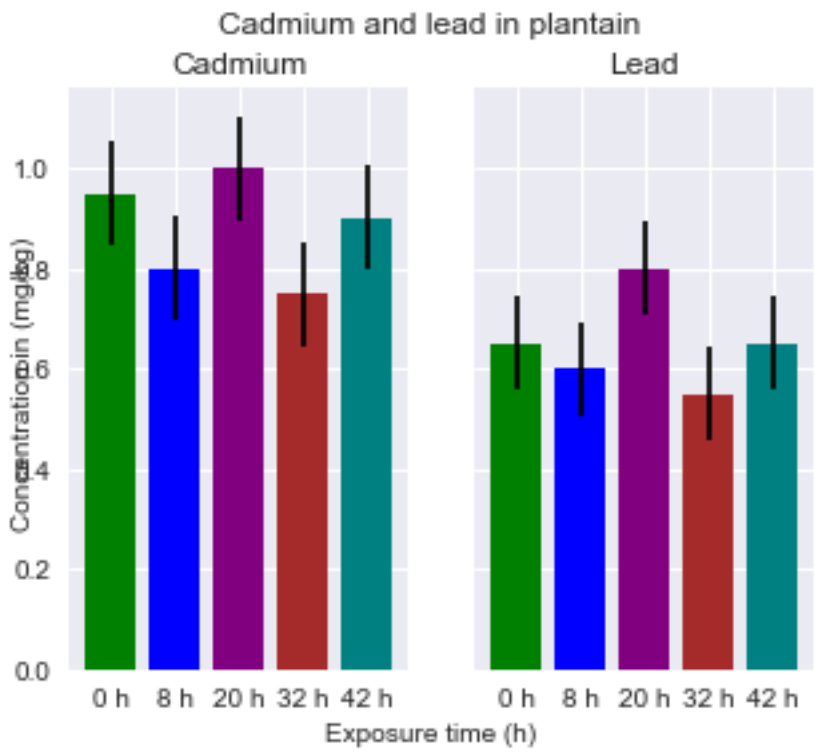


Figure 9: Concentration of Cd and Pb in plantain for different exposure times

Conclusion

The effect of atmospheric deposition on the concentration of some pollutants in farm products dried along non-vehicular corridors has been investigated and determined using Atomic Absorption Spectrometry (AAS). The concentration of the heavy metals, Cu, Zn, Mn, Ni, Cd, and Pb in exposed samples was impacted, in a non-uniform pattern, and to varying degrees, for the different exposure periods, by atmospheric deposition. The non-uniform pattern might have resulted from differences in the concentrations of these heavy metals in the atmosphere. It could also be attributed to the different water retention abilities of the respective farm products, which may either enhance or hamper the absorption or evaporation of deposited pollutants on these farm products. The study, therefore, concludes that the effect of atmospheric deposition on the concentration of exposed farm products may not be dependent on the exposure time but on the concentration of the pollutant in the atmosphere and perhaps the water retention ability of the farm produce.

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