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Research Paper

Ambient Air Quality Monitoring Procedure via Estimation of Cadmium and Lead Content in Atmospheric Dust Using Vegetable Leaves

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Abstract

Dust emitted into the air through human activities reduces air quality because it comes along with its deleterious constituents. This study aims to monitor the ambient air quality via the estimation of cadmium and lead concentration in the dust-polluted atmospheric environment using vegetable leaves. Leaves of pumpkin (*Telfairia Occidentalis*) and green (*Amaranthus hybridus*) vegetables obtained from Oba, Ekiosa, New Benin, and Ikpoba-Hill markets in Edo State, Nigeria, were washed with de-ionized water, spread, and exposed on tables placed at ten different points, 10 meters apart near the roadside outside and inside each market from 8:00 am to 6:00 pm every day (Monday - Friday) for three months (from November to March). The cadmium and lead pollutants in the dust deposit were analyzed using atomic absorption spectrophotometer after wet digestion of the different collectors. The study revealed that there was no cadmium content in the dust deposited on the vegetable leaves exposed inside each market. Atmospheric dust deposited on the vegetable leaves outside each market had cadmium content up to the tune of ≤0.01mg/kg. The study also revealed that the atmospheric dust inside and outside each market contained lead content. The lead content in the dust deposit obtained from outside each market ranged from 0.03-1.04 mg/kg, and the lead content in the atmospheric dust deposit obtained from inside each market ranged from 0.02-0.69 mg/kg. The air quality index (AQI) prediction for cadmium inside and outside the market atmosphere was very good (very clean). However, for the lead contaminant, the AQI rating outside and inside the market ranged from moderate (fairly clean) to very poor (severely polluted). Ekiosa market was very poor (severely polluted) and the Ikpoba-Hill market was moderate (fairly clean) due to lead contaminants in dust deposited due to human activities and heavy vehicular traffic.

1. Introduction

Dust is one of the air pollutants that can be emitted into the air thereby reducing air quality because of its deleterious constituents (Mehrizi et al., 2017). Dust deposition is an ambient air quality indicator monitor (Atef et al., 2020). The constituents and quantity of poisonous elements in dust are pointers to the poor quality of the urban environment (Hemati and Rahimi, 2020; Kaonga et al., 2021; Vanegas et al., 2021). Dust particle comprises sizeable amounts of poisonous substances that present threats to the health of living organisms and ecosystems (Esfandiari et al., 2019). Dust is airborne particulate matter in the form of fine powder with tiny solid particles ranging in size from beneath 1 μm to 100 μm. Dust is either lying on the ground or the surface of objects or scattered or suspended in the air (Nwosu et al., 2016; Srivastava et al., 2020; Kaonga et al., 2021).

Dust chemical constituents are inconsistent and linked with the features of the emission sources. The dust particles contain pollutants such as "inorganic"

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(heavy metals), "organic" (polycyclic aromatic compounds) and biological materials (micro-organisms), depending on the source of the dust (Sun, 2017; Kumari et al., 2021; Vanegas et al., 2021). The traffic zone is deemed the main provider of heavy metal emission and dust particles ≤10 μm (Javid et al., 2021). The existence of heavy metals in dust existing in the air raises the concentration of these elements in the human body via ingestion, respiration as well as skin absorption (Abdel et al., 2016; Javid et al., 2021; Hamed et al., 2022).

Owing to fast-tracked social and economic growth, there is a rise in heavy metals in urban road dust due to anthropogenic sources which comprise traffic discharge such as vehicle exhaust particles, tire attrition particles, eroded street surface particles, brake lining attrition particles, etc. (Rajeswari and sailaja, 2014; Osakwe and Okolie, 2015; Altaf et al., 2021); industrial discharge such as power plants, coal combustion, metallurgical industry, auto repair shop, chemical plant, etc.; domestic discharge such as electric generator discharge, building and pavement surface wear away, atmospheric deposits and the like, thereby causing a growing number of pollutants to be regularly emitted into the environment (Masindi and Muedi, 2018; Okunlola, 2019; Xu et al., 2021; Su, 2022). Ingestion of dust particles loaded with high concentrations of heavy metals may trigger respiratory and cardiovascular diseases, cancer, birth flaws, central nervous system impairment and death (Al-Dabbas et al., 2018; Skorbiłowicz et al., 2020; Kaonga et al., 2021). Lead is released as lead (II) oxide (PbO) into the atmosphere through oil combustion, as lead (II) sulphate ($PbSO_4$) and PbO through non-ferrous metal production, and it is emitted as Lead (II) chloride ($PbCl_2$) during coal combustion, refuse incineration and vehicle exhaust emission. Cadmium is released into the air as cadmium (II) oxide (CdO) by anthropogenic sources, as cadmium (II) sulphide (CdS) through coal combustion, as cadmium (II) chloride ($CdCl_2$) through refuse incinerator, and as elemental cadmium in the course of high-temperature means, for instance, organic fossil fuel combustion and waste incineration (W.H.O, 2007; Engwa et al., 2019). Cadmium triggers off injuries to the kidney, and acute pulmonary effects as well as kidney cancer. It also affects the liver and gastrointestinal tract. Similarly, lead injures the kidney, affects the nervous system, and triggers mental lapse (Ojo, 2017; Skorbiłowicz et al., 2020).

Kananke (2014) asserted that nearly all eaten green leafy vegetables sold along the roadside open markets in highly urbanized areas are contaminated with heavy metals. Metals monitoring in atmospheric dust deposits is conventionally executed by using collectors which are dispersed all over areas envisioned to be monitored. In this study, leaves of pumpkin (*Telfairia Occidentalis*) and green (*Amaranthus hybridus*) vegetables were used as our dust collectors based on their availability, cheapness, toughness and ease of digestion.

This research is aimed at estimating cadmium and lead concentration in the dust-polluted atmospheric environment as well as predicting its ambient air quality with the aid of vegetable leaves as a dust collector.

2. Materials and Methods

2.1. Study Area, Sampling & Sample Preparation

The study areas used for this research were Oba market (OM) (6020'5" N; 5037'11" E), the Ekiosa market (EM) (6019'24" N; 5038'11" E) and New Benin market (NBM) (6021'13" N; 5037'53" E) (all located in Oredo Local Government area, Nigeria) as well as Ikpoba-Hill market (IHM) (6020'56" N; 5039'33" E) located in Ikpoba-Okha area in Edo State, Nigeria. These markets were selected for this study because the roads on the sides of these markets are busy with high human activities as well as vehicular traffic.

The monitoring systems were used in collecting dust samples before analysing the composition of pumpkin leaves (Telfairia Occidentalis) and green (Amaranthus hybridus) vegetables which were purchased and used at each market. After the leaves had been acquired, they were washed in de-ionized water, spread and exposed on tables with a height of 1.0m (sitting height) placed at ten different points the interval of 10 meters from each other near the roadside outside each market mentioned above from 8:00 am to 6:00 pm every day (Monday - Friday) for three months from November to March. Likewise, the vegetables were also exposed on tables inside the market about 150 meters from the roadside. After everyday exposure, the leaves from the different vegetables were plucked off separately and shared into two equal portions of the same weight. One portion was washed thoroughly in de-ionized water and the other portion was left unwashed. This procedure was carried out for vegetables exposed inside and outside the market near the roadside. Each portion of the leave from the different vegetables was oven-dried to constant weight and crushed in a mortar to powdery form and sieved with 53µm mesh size (270-ASTM-E_{11}).

One gram (1g) of the powdered vegetable leaves from each portion was weighed and digested using a wet digestion procedure adapted from Motsara and Roy (2008). Thereafter, the cadmium and lead content in the samples was analyzed using atomic absorption spectrophotometer (AAS) model 210VGP – Buck scientific. This approach to estimating the cadmium and lead in atmospheric dust deposits inside and outside each market was based on data obtained from atmospheric dust deposited on the leaves of the vegetables. The total cadmium and lead in the atmosphere inside and outside each market were estimated based on separate assessments for washed and unwashed vegetable leaves after atmospheric deposition of dust, using equation 1:

$$AD_{HM} = HM_{uwv} - HM_{wv} \quad (1)$$

Where AD_{HM} = total heavy metal in atmospheric dust, HM_{uwv} = total heavy metal in unwashed vegetable leaves, and HM_{wv} = total heavy metal in washed vegetable leaves.

Air quality index (AQI) is a scale to characterize the extent of ambient air pollution at a particular monitoring location during a certain monitoring period as a result of the strength of human activities that occur in an environment. AQI is a rating scale for outdoor air and is rated inversely to the quality of air, that is, the lower the AQI value, the better the air quality. Air quality rating of each quality parameter or pollutant (here Cd and Pb only) was computed using equation (2) (Njoku *et al.*, 2016; Hashmi *et al.*, 2017):

$$Q = \frac{P_o}{P_s} \quad (2)$$

Where, Q = air quality index (AQI), P_o = the observed value of the air quality parameter pollutant (Cd, Pb), P_s= the standard value for that pollutant recommended by WHO.

It is assumed that all the parameters have equal importance, so only the unweighted air quality indices are calculated (Ravikumar et al., 2014). The geometric unweighted AQI may be computed from the air quality rating Q by taking their geometric mean.

$$AQI = [\pi Q_{i=1}^{n}]^{1/n} \quad (3)$$

This relation is made easier to some extent by taking the common logarithm on both sides assuming $\pi = 1$ then,

$$\text{Log AQI} = \frac{1}{n}[\text{Log } Q_1 + \text{Log } Q_2 + \ldots + \text{Log}Q_n] \quad (4)$$

Combining the right-hand side factors

$$\text{Log AQI} = \frac{1}{n}[\sum_{i=1}^{n} \text{Log}Q_i] \quad (5)$$

$$\text{Hence, AQI} = \text{Antilog }(\frac{1}{n}[\sum_{i=1}^{n} \text{Log}Q_i]) \quad (6)$$

The ambient air quality index can be calculated using equations 1 and 6. The seven grades of air quality categories include: very clean (AQI < 10), clean (10 ≥ AQI < 25), fairly clean (25 ≥ AQI < 50), moderately polluted (50 ≥ AQI <75), polluted (75 ≥ AQI < 100), highly polluted (100 ≥AQI < 125) and severely polluted (AQI ≥ 125). Based on these standard AQI values, the air quality of the observed air samples can be compared and inferred (Ravikumar et al., 2014). The five-grade air quality scale, according to Njoku et al., (2016), is as follows: A = Very good (0 -15), B = Good (16 -31), C = Moderate (32 – 49), D = Poor (50 – 99) and E = Very poor (100 and over).

2.2.Quality Assurance

Suitable quality assurance and safety measures were obeyed to guarantee test results' dependability. Analytical and trace-metal grades reagents/chemicals, de-ionized water as well as washed glassware and utensils were utilized during the research. Samples were carefully managed to lessen cross-contamination. Reagent blank determinations were also carried out to correct the instrument readings.

2.3.Statistical Analysis

Descriptive statistics such as mean, standard deviation, and analysis of variance (ANOVA) were carried out to correlate the significant differences for the examined metals between the different selected sites.

3. Results and Discussion

3.1. Mean Content of Cadmium and Lead in Dust Deposited on Washed and Unwashed Vegetables Leaves

The results obtained from the study showing the content of cadmium and lead in washed and unwashed vegetables after exposing them outside and inside the different markets are presented in Table 1 and Table 2 in that order. The results obtained for vegetable leaves exposed to … outside the markets (Table 1) show that the values of the amount of lead in atmospheric dust deposited on the unwashed green vegetable leaves were higher than those obtained in the atmospheric dust deposited on the pumpkin leaves probably due to adsorption or roughness of leave surfaces. The lead content on the washed vegetable leave depicted the value of lead in the vegetable from the source farm. The lead amount from the washed green leave was lesser than that from the washed pumpkin leaves depending on the farm source except for the vegetables from the New Benin market (Table 1). However, the amount of lead observed from the unwashed vegetable leaves was higher than the amount from the washed vegetable leaves, indicating that lead-laden dust was deposited on the unwashed vegetable leaves due to high vehicular traffic as well as other human activities. Likewise, the amount of cadmium in the dust deposited on the unwashed vegetable leaves was higher. The value of cadmium obtained from the washed vegetable leave was below the detectable level (BDL), indicating that the cadmium content in the vegetable leave used for this study was originally below the detectable level from the farm source except for the vegetable leave used in Ekiosa market, which contained 0.01mg/kg from farm source.

Table 1: Mean Content of Cadmium (Cd) and Lead (Pb) on Washed and Unwashed Vegetables Leaves after Exposure outside the Market per Day.

Collector	Locations	Unwashed leaves		Washed leaves	
Vegetable		Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Pumpkin	Oba Market	0.01± 0.003	1.24± 0.02	BDL	0.74± 0.01
Green	Oba Market	0.01± 0.002	1.47± 0.03	BDL	0.43± 0.01
Pumpkin	Ekiosa Market	0.02± 0.005	0.72± 0.01	0.01± 0.002	0.36± 0.05
Green	Ekiosa Market	0.01± 0.003	0.97± 0.02	0.01± 0.002	0.30± 0.04
Pumpkin	New Benin Market	0.01± 0.002	0.82± 0.02	BDL	0.45± 0.05
Green	New Benin Market	0.01± 0.003	1.12± 0.02	BDL	0.86± 0.01
Pumpkin	Ikpoba-Hill Market	0.01± 0.002	0.58± 0.01	BDL	0.55± 0.01
Green	Ikpoba-Hill Market	0.01± 0.002	0.74± 0.02	BDL	0.36± 0.05

BDL= Below Detectable Level

Table 2: Mean Content of Cadmium and Lead in Washed and Unwashed Vegetables Leaves after Exposure inside the Market per Day

Collector	Locations	Unwashed leaves		Washed leaves	
Vegetable		Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
Pumpkin	Oba Market	BDL	1.07±0.02	BDL	0.63±0.01
Green	Oba Market	BDL	0.84±0.03	BDL	0.63±0.02
Pumpkin	Ekiosa Market	0.01±0.002	0.63±0.01	0.01±0.002	0.20±0.01
Green	Ekiosa Market	0.01±0.002	0.89±0.04	0.01±0.002	0.20±0.01
Pumpkin	New Benin Market	BDL	0.45±0.02	BDL	0.20±0.02
Green	New Benin Market	BDL	0.86±0.03	BDL	0.56±0.02
Pumpkin	Ikpoba-Hill Market	BDL	0.57±0.01	BDL	0.55±0.01
Green	Ikpoba-Hill Market	BDL	0.58±0.01	BDL	0.36±0.01

BDL= Below Detectable Level

The results obtained from vegetable leaves exposed inside the market (Table 2) show that the amount of lead in the atmospheric dust deposited on the unwashed green vegetable leaves was higher than that in the atmospheric dust deposited on the pumpkin leaves except for Oba market, where the amount of lead from the atmospheric dust deposited on the pumpkin leaves was higher than that of the green vegetable. The amount of lead observed from the unwashed vegetable leaves was higher than that from the washed vegetable leave, indicating that lead-laden dust was deposited on the unwashed vegetable leaves even inside the market. This could be due to the use of diesel and petrol engine grinding machines as well as other human activities inside the market. The cadmium content in the dust deposited on the unwashed and washed vegetable leave was below detectable level except for pumpkin leave and green leaves exposed at Ekiosa market which implies it was from the farm source.

3.2. Mean Content of Cadmium and Lead in the Atmospheric Dust Deposited on Vegetable Leaves

The results of the amount of cadmium and lead obtained in the atmospheric dust deposited on the different vegetable leaves outside and inside each market per day are presented in Table 3. In all the market locations, the values of cadmium content obtained in the atmospheric dust deposited on the vegetable leaves exposed outside the market were higher than the values exposed inside the market. In like manner, the lead content obtained in the atmospheric dust outside the market was higher than that obtained in the atmospheric dust inside the market. However, the lead content in dust deposited on the leaves of green vegetables and pumpkins inside the Ekiosa market was higher than those obtained from outside the market (Table 3). This indicates that there could be heavier human activities resulting in the emission of lead inside the Ekiosa market compared to the other three markets.

The lead content in the atmospheric dust deposited on pumpkin leaves from outside each market ranged from 0.03-0.50mg/kg, and the atmospheric dust deposited on the green leaves from outside each market ranged from 0.26-1.04mg/kg. This observation could be a result of the higher adsorptive strength of the green leaves for lead compared to pumpkin leaves. The lead content in the atmospheric dust deposited on the pumpkin leaves inside each market ranged from 0.02-0.44mg/kg, and the atmospheric dust deposited on the green leaves inside each market ranged from 0.21-0.69mg/kg and this observation could be attributed to the fact that the green leaves had higher adsorptive strength for lead compared to pumpkin leaves. The analysis from the study revealed that there was no cadmium content in the atmospheric dust deposited on both vegetable leaves exposed inside the market, indicating that whatever amount of cadmium observed

Table 3: Mean Content of Cadmium and Lead in the Atmospheric Dust Deposited on the different Vegetable Leaves outside Market and inside each Market per Day

Collector (with a location in	Outside Market Dust		Inside Market Dust	
	Cd mg/kg	Pb mg/kg	Cd mg/kg	Pb mg/kg
Pumpkin(OM	0.01	0.50	BDL	0.44
Green(OM)	0.01	1.04	BDL	0.21
Pumpkin(EM	0.01	0.36	0.00	0.43
Green(EM)	0.00	0.67	0.00	0.69
Pumpkin(NB	0.01	0.37	BDL	0.25
Green(NBM)	0.01	0.26	BDL	0.30
Pumpkin(IH	0.01	0.03	BDL	0.02
Green(IHM)	0.01	0.38	BDL	0.22
WHO, 2004	2.0	0.5	2.0	0.5

BDL= Below Detectable Level

concerning vegetables exposed inside the market was from a farm source; this implied that there was no cadmium content inside the market atmosphere. However, due to heavy traffic and other human activities outside the markets, it was observed that the atmospheric dust deposited on the vegetable leaves outside the markets had some content of cadmium up to the tune of 0.01mg/kg. We observed that the cadmium content in the atmospheric dust deposit obtained from the deposit on green leave outside the Ekiosa market was the least, with 0.00mg/kg. This study revealed that there was some cadmium content in the outside market atmosphere. However, the cadmium content in the atmospheric dust outside the markets was below the WHO standards of 2.0 mg/kg (WHO, 2004).

The value of lead content in the atmospheric dust deposited on the vegetable leaves inside and outside the markets revealed that the atmospheric dust inside and outside the market was contaminated with lead content. The lead content present in the atmosphere inside the market could be due to petrol and diesel engine grinding machines and some other anthropogenic activities, while the lead content in the atmospheric dust outside the market was probably due to heavy vehicular traffic and other anthropogenic activities such as fossil fuel combustion as well as waste incineration.

3.3. Prediction of Air Quality outside and Inside Each Market Atmosphere

Prediction of air quality outside and inside each market atmosphere per day for cadmium and lead contaminants vis-à-vis WHO standards were made using the estimations obtained from the air quality index (AQI) (Table 4).

The AQI estimates for cadmium inside and outside the atmosphere of each market surveyed were very good (or very clean), rated 'A' that is its air quality index was less than 10.00 (AQI< 10) (Table 4). The air quality index revealed that the atmosphere outside and inside Oba market (OM) was very poor (or highly polluted) and poor (or polluted) respectively with the use of pumpkin leaves. Likewise, the air quality rating for the atmosphere outside and inside Oba market (OM) was very poor (or severely polluted) and moderate (or fairly clean) respectively with the use of green leaves due to lead contaminant. The air quality index rating revealed that the atmosphere outside and inside Ekiosa market (EM) was poor (moderately polluted or polluted) with the use of pumpkin leaves, whereas the rating with the use of green leave revealed that the atmosphere outside and inside Ekiosa market (EM) was very poor (severely polluted) due to lead contaminant. The atmosphere outside and inside the New Benin market (NBM) was rated poor (or moderately polluted) due to lead contaminants with the use of pumpkins or green leaves. The air quality rating with the use of pumpkin leaves

Table 4: Air Quality Index (AQI) outside and inside Each Market Atmosphere per Day for Cadmium and Lead Contaminants.

Collector (with a location in Abbreviations)	Outside Market Dust				Inside Market Dust			
	Cd (mg/kg)	AQI	Pb (mg/kg)	AQI	Cd (mg/kg)	AQI	Pb (mg/kg)	AQI
Pumpkin(OM))	0.01	0.50	0.50	100.00	BDL	0.00	0.44	88.00
Green(OM)	0.01	0.50	1.04	208	BDL	0.00	0.21	42.00
Pumpkin(EM)	0.01	0.50	0.36	72.00	0.00	0.00	0.43	86.00
Green(EM)	0.00	0.00	0.67	134.00	0.00	0.00	0.69	138.00
Pumpkin(NBM)	0.01	0.50	0.37	74.00	BDL	0.00	0.25	50.00
Green(NBM)	0.01	0.50	0.26	52.00	BDL	0.00	0.30	60.00
Pumpkin(IHM)	0.01	0.50	0.03	6.00	BDL	0.00	0.02	4.00
Green(IHM)	0.01	0.50	0.38	76.00	BDL	0.00	0.22	44.00
WHO standard, 2004	2.0mg/kg		0.5mg/kg		2.0 mg/kg		0.5 mg/kg	

BDL= Below Detectable Level

revealed that the atmosphere outside and inside Ikpoba hill market (IHM) was very good (or very clean). However, with the use of green leave, the atmosphere outside Ikpoba hill market was poor (or polluted) and the atmosphere inside the market was moderate (or fairly clean) due to lead contaminant.

4. Conclusion

This study has usefully determined the quantity of cadmium and lead in atmospheric dust in a polluted atmosphere as well as predicted the air quality inside and outside the market atmosphere with the use of vegetable leaves as a collector. This procedure was not affected by heavy metal interference from the farm soil or accumulated metals in the vegetable leaves because the washed and unwashed vegetable leaves were from the same source, thus cancelling out the effect of heavy metal interference from the farm source (a kind of levelling effect). This assessment procedure has portrayed the presence and estimation of cadmium and lead in atmospheric dust and predicted their air quality due to the effect of human activities and vehicular traffic.

Implication: Monitoring, evaluating, and assessing environmental air quality and effects related to cultural heritage are very important to allow for timely action of preventing irreversible losses. The findings herein depict a means of obtaining baseline data that will help create awareness of the consequences of vehicular traffic, fossil fuel combustion as well as incineration of waste near the markets in the Oredo and Ikpoba-Okha Local Government Area. This ambient air quality monitoring procedure for determining cadmium and lead content in atmospheric dust will help in quick and regular monitoring to ensure suitable management of the market and urban environment. It is expected that the AQI rating for ambient air using this monitoring procedure will help to generate data for further research on air quality control and management.

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