PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 29 (1) 85-93 Jan. 2025

Evaluation of Cadmium Contaminations in Soil and Plants, and Potential Ecological Risk at a Tertiary Institution Campus, Malete, Kwara State, Nigeria

*** BEN-UWABOR, PO; OLARINOYE, SO**

**Department of Plant and Environmental Biology, Faculty of Pure and Applied Sciences, Kwara State University, Malete, Kwara State, Nigeria*

**Corresponding Author Email: patience.ben-uwabor@kwasu.edu.ng*
**ORCID: https://orcid.org/0009-0007-5887-1385*
**Tel +2348033701890*

Co-Author Email: olarinoyeolajide42@gmail.com

ABSTRACT: The objective of this paper is to evaluate the cadmium contaminations in soil and plants, and potential ecological risk at a tertiary institution campus, Malete, Kwara State, Nigeria using appropriate standard procedures. Data obtained indicates highest cadmium concentration in plants at the library (0.282±0.03 mg/kg), while the highest soil concentrations were observed at the School Park (0.316±0.04 mg/kg). The cadmium Contamination Factor (CF) and Bioaccumulation Coefficient (BAC) assessed the degree of pollution on the campus and the amount of Cd uptake by the plants, with moderate contamination across most sites, recording the Administrative Building area to display a notably higher Contamination Factor of 2 and cadmium Potential Ecological Risk index of 60, indicating a moderate ecological risk with *Azadirachta indica* and *Delonix regia* been hyperaccumulators of cadmium.These findings showed the need for cadmium monitoring and targeted friendly environmental management, particularly in areas with elevated cadmium levels. The study concludes that while cadmium contamination is a campus-wide issue, specific locations, such as the Library and Administrative Building, require urgent attention to mitigate potential environmental and public health risk.

DOI: https://dx.doi.org/10.4314/jasem.v29i1.12

Cite this Article as: BEN-UWABOR, P. O; OLARINOYE, S. O. (2025). Evaluation of Cadmium Contaminations in Soil and Plants, and Potential Ecological Risk at a Tertiary Institution Campus, Malete, Kwara State, Nigeria. *J. Appl. Sci. Environ. Manage.* 29 (1) 85-93

Dates: Received: 22 October 2024; Revised: 20 November 2024; Accepted: 28 December 2024; Published: 31 January 2025

Keywords: Anthropogenic influence; Cadmium Pollution; Environmental Contamination; Tertiary institution campus; Environmental assessment

Cadmium is a highly toxic heavy metal known for its detrimental effects on the environment and human health. It is frequently introduced into the environment through industrial activities such as mining, metal processing, agricultural practices, vehicular emissions, and the production of batteries and plastics. Once present, cadmium can persist for decades, posing significant risks to both ecosystems and human well-being (Crock *et al.*, 2019).The environmental presence of cadmium is particularly alarming due to its toxicity at even low concentrations. It can accumulate in living organisms, leading to bioaccumulation and biomagnifications through food chain. In humans, exposure to cadmium is associated with serious health issues, including kidney damage, bone demineralization, and an increased risk of cancer (WHO, 2019). Cadmium (Cd) is a toxic heavy metal that poses significant environmental and health risks (WHO, 2019). It is a naturally occurring element in the earth's crust, but human activities have increased its release and dispersion in the environment (Kabata-Pendias and Mukherjee, 2001). Cadmium occurs in naturally high abundance in zinc and lead ores and in

**Corresponding Authors Email: patience.ben-uwabor@kwasu.edu.ng*
**ORCID: https://orcid.org/0009-0007-5887-1385*
**Tel +2348033701890*

phosphate fertilizers (McLaughlin and Singh, 2019). High concentrations of cadmium were also found in some sewage sludge. Agricultural uses of phosphate fertilizers, sewage sludge and industrial uses of cadmium have been identified as a major cause of widespread dispersion of the metal at trace levels into the general environment and human foodstuffs. Other causes of cadmium dispersion are enhanced natural emission and bioaccumulation taking place in certain plants, mammals and filter feeder organisms including crustaceans and mollusks (Crock *et al*., 2019). Cadmium in soils is known to be more mobile and readily absorbed and incorporated into plant tissues compared with lead and mercury (Scheuhammer, 2018). Cadmium can accumulate in soil, leading to long-term contamination and potential uptake by plants (Kabata-Pendias and Mukherjee, 2019), water bodies, posing risks to aquatic life and human health (WHO, 2019) and in air leading to air pollution, contributing to respiratory problems (EU, 2019). Plants are known to tolerate cadmium well and as a result cadmium toxicity in plants occurs at higher concentrations than those causing toxicity in humans and animals. Indeed, adverse effects of cadmium entering the food chain of some wild animals have recently been reported. Classic symptoms of cadmium toxicity in bone were found in female white-tailed ptarmigan (*Lagopus leucurus*) that feed heavily on willows (*Sallix glauca*). The willow has a greater ability to bioaccumulata cadmium from soils compared with other plant species of the same area (Crock *et al*., 2019). High levels of cadmium were found in liver and kidney samples of moose (*Alces alces*); another animal species known to normally eat large quantities of willows (Kim *et al*., 2018). In early studies, seabirds, starlings (*Sturnus vulgaris*), Japanese quails (*Coturnex coturnex*) were also found to be susceptible to cadmium that entered their food chain (Gochfeld, 2020).

Cadmium exposure causes kidney dysfunction and increase the risk of kidney disease, bone disease, causing bone weakness and increase the risk of osteoporosis and lung damage and increase the risk of lung disease (IARC, 2019). Environmental assessment of cadmium pollution is crucial in order to monitor and track cadmium levels in soil, water, and air thereby monitoring and assess the trends and identify areas requiring remediation (Hossain *et al*. 2018). This will also enable the evaluation of the potential health risk of the heavy metal to humans and wildlife, enabling informed decision-making (IARC, 2019). Thereby proffer appropriate remediation strategies and management practices, minimizing environmental and health impacts in compliance with the environmental regulations and standards (Alloway *et al*., 2017).

Kwara State University, situated in Malete, Kwara State, Nigeria, offers a unique setting for examining cadmium pollution due to its diverse activities and proximity to agricultural and urban areas. Previous studies have documented varying levels of heavy metal contamination across different regions of Nigeria, specific data on cadmium pollution within university campuses is limited (Edogbo, *et al.*, 2020). Hence, the objective of this paper is to evaluate Cadmium contaminations in soil and plants and potential ecological risk at a tertiary institution campus, Malete, Kwara State, Nigeria.

MATERIALS AND METHODS

Description of study area: The study area is Kwara State University campus, in Malete, Kwara, Nigeria. It is a university located in Malete, in the Ilorin West Local Government Area of Kwara State, Nigeria. It is a dynamic institution committed to fostering academic excellence, research innovation, and community engagement. Its coordinates are approximately 8.7114° N latitude and 4.4519° E longitude.

It has different entrepreneurial outfits such as agricultural farms where crops and poultry products are sold, water factory, commuter services, printing and photocopying centers business centers and lots more. Different activities that can contribute to environmental pollution in the campus include the vehicular emission, exhausts from powerhouse and generating sets from different sources, agricultural practices, exhausts from laboratories, waste disposal from offices, hostels, laboratories, offices, fumigation, noise and lots more.

Sample collection: Soil and plant sample collection: About one kilogram of composite soil was collected in a well labeled, clean and sterile zip lock bag from each site of the University as represented above in Table 1. At each site where soil was collected, the most abundant plant was collected in another well labeled, clean and sterile polyethylene bag. A control soil and plant sample were taken from a less anthropogenic area (School chapel), where human activities are less. These were all transported to the Chemistry Laboratory department at the University of Ilorin for preparation and further analysis.

Soil preparation.: Prior to the analysis, each soil collected sample was prepared or pre-treated before being analyzed using the method of Taiwo *et al.* (2021). 1 kg composite soil sample from each study site was sieved through a 2 mm sieve to eliminate stones and other extraneous materials from the soil. The sieved soils were separately spread over a polyethylene sheet and air-dried at room temperature for one week. Samples were separately ground to a fine powder in a tungsten-carbide swing mill for 3 mins and sieved through a <1 µm sieve. After which a heavy metal (Cd) analysis was conducted.

Table 1: Sampling Areas of Soil and Plant Samples (Kwara State University, Malete) and Their Coordinates

S/N	Sampling Areas	Plant Common Name	Botanical Name	Activities Around the Sampling Point	GPS Coordinate
1	School chapel	Lemon-scented gum	*Croymbiacitrodora*	Farming	8.71911°N 4.48830°E
2.	HMSS	Emblica	*Phyllanthus emblica*	Schooling	8.72129°N 4.48642°E
3.	Administrative building	Flame of woods	*Ixora coccinea*	Schooling	8.71953°N 4.48549°E
4	School Park	Royal poinciana	*Delonix regia*	Trading	8.71805°N 4.48440°E
5.	School library	Neem tree	*Azadirachta indica*	Schooling	8.72142°N 4.48451°E
6.	Safari	Pignut	***Conopodium** majus*	**Market place** (Trading)	**8.70469°N** 4.46724°E

HMSS building=Humanity Management and Social Sciences. KWASU=Kwara State University.

Plant preparation: Each plant sample was thoroughly washed with distilled water to remove the extraneous materials and samples were cut into sizeable pieces using a knife and they were sun dried. These were later placed in an oven set at 50 °C for 2 days for complete dryness. The dried samples were then ground using blender (Model 33750), into fine powdery form. Each of the samples was stored in well labeled plastic containers for cadmium analysis using the methods of Jawad *et al*.(2010) and Lawal *et al*. (2011).

Cadmium analysis in soil samples: The Aqua Regia method was used to determine the cadmium (Cd) content in each sampled soil. Each pre-treated soil sample was analyzed of heavy metal (Cd) using the wet- digestion method of Ghosh *et al*. (2012) and Atomic Absorption Spectrometer. 1g of each air-dry sample (soil sample) was weighed into a conical digestion flask. 15ml of concHNO_3 and 3ml of Conc. HCL were added into the sample in the digestion flask. The soil sample was heated on a hot plate until all the brownish flumes expelled out (Nitrogen compound) which confirmed the complete digestion of the soil sample. The sample was allowed to cool at room temperature and a few m/l of distilled water was added and the mixture was filtered into 50ml flask using a Whatman No 42 Filter paper. This was made up to mark with distilled water and was transferred into a well labeled, clean and sterile reagent bottle for A.A.S (Atomic Absorption Spectrometry).The Cd content was determined by Atomic Absorption Spectrometry using An Analyst 200 Perkin Erlymer. Quality control was assured by running the procedure in triplicate to check errors and the use of blanks to check for background contamination of the reagents used. A certified reference material (CRM: IAEA-SL-1-lake sediment) was digested along with the samples and the recovery percentage of the CRM was between 88%-98%. (International Atomic Energy Agency, Vienna, Austria) to authenticate the digestion processes.

Cadmium determination in plant samples: The Aqua Regia method was used to determine the cadmium (Cd) content in each sampled plant. Each ground plant sample was digested and analyzed with Cd. 0.25 g of each ground sample was weighed into a 50 ml beaker followed by the addition of 10mlsof 6 M HCl in triplicate (Ebong *et al*., 2008). The beaker containing the samples was covered and heated for about 15 minutes. This was followed by the addition of 1ml Conc. HNO_3. The digestion was performed at 95°C until about 4 ml of the solution was left in the beaker. 1ml 6 M HCl was added, swirled and 10 ml of distilled water was added. The beaker was heated again on the steam bath to ensure complete dissolution. This was allowed to cool, after cooling, the solution was filtered using a Whatman No. 42 filter paper into a 50 ml volumetric flask and made up to a mark with distilled water for instrumental analysis (Echem, 2014). The Cd content in each digested sample was determined by Atomic Absorption Spectrometry using A Analyst 200 Perkin Erlymer. Certified reference material IAEA 359 (cabbage) was digested and percentage recoveries for the Cd was calculated to validate the procedure

Contamination Factor (CF) for Cadmium (Cd): The Contamination Factor (CF) of cadmium in the soil samples was evaluated according to the method of Hakanson (1980). Contamination Factor is a measure used to assess the degree of contamination of heavy metal in soil. It was calculated by comparing the concentration of the cadmium in the soil sample with its background (control) concentration. Contamination Factor (CF) for Cadmium (Cd) in each soil sample was evaluated in equation 1.

$$CFCd = \frac{CCd}{BCd} \quad (1)$$

Where: C_{Cd} is the measured concentration of cadmium in the soil or sediment (mg/kg); B_{Cd} is the background concentration of cadmium in the soil or sediment (mg/kg).

Interpretation: CF<1: Low contamination; 1≤CF<3: Moderate contamination; 3≤CF<6: Considerable contamination; CF≥6: Very high contamination

Bioaccumulation Coefficient (BAC) of cadmium (Cd) in plant species: The Bioaccumulation Coefficient (BAC) was evaluated by the method of Ogunkunle *et al*. (2015). BAC quantifies the accumulation of Cd in the plant relative to the concentration in the surrounding environment. This coefficient helps assess how much Cd is retained by plant compared to the amount in the environment. BAC is a significant measure of the bioaccumulation potential of the plant species to Cd in their environments, which may raise concerns about the ecological and health impacts of this heavy metal (Cd) on the plants. It is also a measure of the phytoremediation potential of the plant species to Cd in their environment. The Bioaccumulation Coefficient (BAC) of Cd in each plant was calculated in equation 2.

$$BAC = \frac{Cp}{Ce} \quad (2)$$

Where: C_p is the concentration of the substance in the tissue of each plant (mg/kg); C_e is the concentration of the substance in the soil where each plant was collected (mg/kg).

Interpretation: The Bioaccumulation Coefficient (BAC) indicates how efficiently a substance (Cd) accumulates in a plant species compared to its environmental concentration: BAC < 1: The substance is less concentrated in the plant than in the environment. This suggests low bioaccumulation potential; BAC = 1: The substance is at equilibrium between the plant and the environment, indicating no net accumulation; BAC > 1: The substance is more concentrated in the plant than in the environment, suggesting significant bioaccumulation.

Potential Ecological Risk Index (PERI) of cadmium (Cd) in the environment: The Potential Ecological Risk Index (PERI) of Cd was evaluated by the method of Hakanson (1980). This was calculated by combining the contamination factor of Cd with the toxic response factor (TRF) for the Cd in the study areas. The potential ecological risk index of Cd at each sampling site was calculated inequation .

$$PERICd = CFCd \times TRFCd \quad (3)$$

Where: CF_{Cd} is the calculated contamination factor of Cd; $PERI_{Cd}$ is the potential ecological risk index of Cd; TRF_{Cd} is the toxic response factor for Cd, which is a standard factor (Cd = 30)

Interpretation: The interpretation of the ecological risk index (ERI_i) is as follows: ERI<40: Low ecological risk; 40≤ERIi<80: Moderate ecological risk; 80≤ERIi<160: Considerable ecological risk; 160≤ERIi<320: High ecological risk; ERIi≥320: Very high ecological risk

*Data Analysis:*Statistical validation of result was done using SPSS version 21.0 to evaluate the data generated. Descriptive statistics were used for the interpretation of data with Duncan Multiple Range Test. A one-way ANOVA was used to compare cadmium levels across the soil and plant samples at different locations of KWASU, Malete (Ogunkunle *et al*. 2015)**.** All determinations were made in triplicates. Representative results and the data were reported in $mgkg^{-1}$ with the mean values and the standard deviation calculated.

RESULTS AND DISCUSSION

Table 2 shows the result of the cadmium dynamics in plant and soil samples collected from six different locations on Kwara State University campus. Site 1, which is the Kwara State university chapel, was sampled for control experiment because of minimal human activities around the site, though; the result shows elevated value of Cd in the supposed control site than some of the other sites of the campus. The cadmium concentration in the sampled plants ranged from $0.039{\pm}0.00^{e}$ mg/kg to $0.282{\pm}0.03^{a}$ mg/kg, with the lowest Cd content obtained for plant (*Ixora coccinea)* collected from site 3 (AD-Administrative building area) and the highest content for plant (*Azadirachta indica)* collected from site 5 (LB-Library). Higher Cd content was recorded for the control plant (*Corymbia citriodora:* 0.169 ± 0.22^{c} mg/kg*)*, than the Cd content of plant (*Phyllanthus* *emblica:* 0.093±0.00^{de}mg/kg) collected from site 2 HMMS. From site 3(Administrative building), the plant (*Ixora coccinea)* recorded a concentration of 0.039±0.00^{e}mg/kg while the plant (*Conopodium majus*) sampled from site 6 (Safari-market place) recorded 0.145±0.02^{d} mg/kg. Significant difference in the Cd concentration of soils and plants collected from the different parts or areas in Kwara State University campus were recorded at $p \leq 0.05$ as shown in Table 2. The result indicates Cd concentrations of some of the sampled plants higher than the United State EPA (2011) permissible limit for plant (0.1-0.3 mg/kg). The control plant sample recorded an unsafe Cd concentration (0.169±0.22^{c} mg/kg) than the US.EPA (2011) for plants. The significant spatial variation in cadmium concentrations observed across the six sampled sites on the campus aligns with previous studies that have reported heterogeneity in contamination levels within localized environments. For instance, studies conducted in other parts of Africa, such as in Ghana and South Africa, have shown that urban and peri-urban areas often exhibit varying levels of heavy metal contamination due to factors like industrial emissions, traffic pollution, and waste disposal practices (Chen *et al*., 2022).

On the other hand, Cd content of the sampled soils in Kwara State University Campus was between 0.083±0.02^{e}mg/kg and 0.316±0.04^{a}mg/kg. The lowest Cd content of soil of the study site was obtained from site 3 area (Administrative building area) while the highest Cd in soils was gotten for soil of site 5 (Library area) as shown in Table 2 below. The Cd concentration of the control soil (School chapel: 0.217±0.01^{b} mg/kg) had higher value than the soils of all the other sites except site 5 (School Park). The result of Table 2 shows significant difference in the Cd concentrations of soil between sites at $p \leq 0.05$. Table 2 indicates all the experimental values obtained for Cd in soils in this research are below the Environmental Protection Agency (EPA) (1996) acceptable limit for residential soil (2.0 mg/kg). The result indicated that the control site was assumingly of less anthropogenic activities but recorded higher cadmium content than some other sites. This could have been its proximity to agricultural area of the university, hence, disposed to higher Cd sources of contamination from agricultural practices. The findings of this study contribute to the growing body of literature on cadmium (Cd) contamination in urban and semi-urban environments, aligning with similar studies conducted worldwide while also highlighting some unique aspects specific to the Kwara State University campus in Malete, Kwara State, Nigeria.

Table 2. Cadmium Concentration in Plant and Soil (mg/kg) of Study Areas

S/N	Sample Code	Location	Plant Name	Plant	Soil
1	KC (Control)	KWASU chapel	*Corymbia citriodora*	0.169±0.22^{c}	0.217±0.01^{b}
2	HS	HMSS building	*Phyllanthus emblica*	0.093±0.00^{de}	0.194±0.01^{c}
3	AB	Admin building	*Ixora coccinea*	0.039±0.00^{e}	0.083±0.02^{e}
4	SP	School Park	*Delonix regia*	0.220±0.00^{b}	0.316±0.04^{a}
5	LB	Library	*Azadirachta indica*	0.282±0.03^{a}	0.155±0.02^{d}
6	SA	Safari	*Mesosphaerum suaveolens*	0.145±0.02^{d}	0.201±0.028^{bc}

Values are presented in Mean ±std. Cd= Cadmium.EPA (1996) Permissible Limit of Cd: Residential Soil=2.0mg/kg; plant= U.S. Food and Drug Administration (FDA) 0.1-0.3mg/kg. HMSS building=Humanity Management and Social Sciences. KWASU=Kwara State University.

Table 3 presents the Cadmium Contamination Factor (CF) across various locations on the Kwara State University campus. The CF is a crucial indicator that shows the ratio of cadmium concentration in soil compared to that in the control soil which is the reference soil, helping to assess the degree of cadmium pollution in the study sites. Across most locations, including Kwasu Chapel, HMSS, Library, and Safari, the CF is consistently 1 while the Administrative block recorded CF >1 at a value of 0.5. This suggests that the plants in these areas are absorbing cadmium in proportion to its availability in the soil, indicating a uniform level of moderate cadmium contamination while the Administrative block had low Cd contamination at the time of study. However, the School Park presents a notable exception with a CF of 2. This higher value indicates that soil at this site has cadmium concentration relatively higher than its soil concentration. The elevated CF at the school park suggests that this area may be experiencing a higher level of cadmium pollution, which could be due to the Cd from vehicular emission. In this study, the School Park's higher contamination factor (CF = 2) compared to other locations indicates a potential localized source of cadmium pollution, which may be influenced by unique soil properties or localized anthropogenic activities, as has been observed in similar studies on contaminated urban parks as reported by Nouri *et al.* (2017). Furthermore, the identification of *Delonix regia* as a cadmium hyperaccumulator in the School Park mirrors findings from studies on hyperaccumulating plants in urban and industrial zones, such as those in China and India, where species like *Brassica juncea* and *Helianthus annuus* were found to accumulate high levels of cadmium

(Sharma and Sharma, 2019). This finding highlights the need for further investigation or targeted environmental management at the school park to address the potential risk for cadmium contamination.

Table 3. Cadmium Contamination Factor (CF) of Soil of the Study Sites

S/N	Location	Plant Name	CF
1	Kwasu chapel	*Corymbia citriodora*	1
2	HMSS	*Phyllanthus emblica*	1
3	Admin building	*Ixora coccinea*	<1
4	School Park	*Delonix regia*	2
5	Library	*Azadirachta indica*	1
6	Safari	*Mesosphaerumsuaveolens*	1

CF<1: Low contamination; 1≤CF<3: Moderate contamination; 3≤CF<6: Considerable contamination; CF≥6: Very high contamination. Humanity Management and Social Sciences. KWASU= Kwara State University.

Table 4 shows the Bioaccumulation Coefficient (BAC) of cadmium in various plants across different locations on the Kwara State University campus. The BAC measures the extent to which plants accumulate cadmium from the soil into their tissues, thus providing insight into potential health risks and the likelihood of cadmium entering the food chain.

The results show that *Azadirachta indica* at the Library and *Delonix regia* at School Park exhibit the highest BAC values of 2 and 2, respectively. These elevated values suggest that these plants are particularly effective at accumulating cadmium from the soil thereby an ecofriendly species for phytoremediation of Cd. The high BAC in these locations imply significant higher potential health risk, as the accumulated cadmium could be transferred through the food chain, potentially affecting local wildlife and even human health if these plants are part of any local diets or are consumed indirectly. In contrast, other locations show much lower BAC values, with Safari standing out for its particularly low BAF of BAC <1 for *Mesosphaerum suaveolens***.** This minimal cadmium accumulation suggests that the plants in this area pose a relatively low Cd health risk when such plant is consumed by herbivores. Hence, the likelihood of cadmium entering the food chain is significantly low.
Generally speaking, the varying BAC of Cd by plants across the campus indicates that while some areas, such as the KWASU chapel, Library and School Park, may require more intensive monitoring and possibly intervention to mitigate cadmium pollution, other areas like Safari present a much lower risk. The elevated bioaccumulation coefficient (BAC) values observed for plants such as *Azadirachta indica* (neem) and *Delonix regia* align with previous research emphasizing the potential risks associated with the bioaccumulation of cadmium in plant tissues. In particular, similar studies documented the ability of plants to uptake and accumulate cadmium in urban and agricultural soils, with implications for both ecological balance and human health.

Research conducted by Zhang *et al.* (2020) in Kenya and Adewale *et al*. (2021) in Nigeria demonstrated that cadmium-contaminated plants, especially those with high BAC values, can serve as vectors for cadmium entry into the food chain. This concern is especially relevant in this study, where elevated cadmium concentrations in plants could lead to exposure through consumption by herbivores or humans, as cadmium is a well-established toxicant that can accumulate in the kidneys, liver, and bones, leading to serious health issues like renal dysfunction, respiratory problems, and cancer (Järup, 2003). This finding underscores the importance of monitoring and managing cadmium levels in plant species, particularly, those that are part of local diets or used in traditional medicine, such as *Azadirachta indica*. These findings underscore the importance of location-specific strategies for managing cadmium contamination and protecting ecological and public health on the campus.

Table 4. Bioaccumulation Coefficient (BAC) of cadmium Cd in plant (mg/kg)

S/N	Site	Plants	BAC
1	KWASU Chapel	*Corymbia citriodora*	1
2	HM	*Phyllanthus emblica*	<1
3	Administrative Block	*Ixora coccinea*	<1
4	School Park	*Delonix regia*	2
5	Library	*Azadirachta indica*	2
6	Safari	*Mesosphaerumsuaveolens*	<1

BAC < 1: Indicates low bioaccumulation potential; BAC = 1: No net accumulation; BAC > 1: Indicates significant bioaccumulation. Humanity Management and Social Sciences. KWASU= Kwara State University.

Table 5 presents the Potential Ecological Risk Index (PERI) of cadmium across various locations on the Kwara State University campus. The PERI assesses the toxic response value of living individual in an ecological risk posed by cadmium pollution in each area. The results indicate that the school park has the highest PERI value of 60. This elevated risk is directly linked to the higher contamination factor observed in this area, suggesting that cadmium pollution at the school park is severe enough to potentially cause considerable ecological damage to plants, animals and humans. The high PERI value highlights the need for urgent attention, potentially requiring targeted environmental management or remediation efforts to mitigate the harmful effects of cadmium at this site. In contrast, the other locations, including Kwasu Chapel, HMSS, Administrative block, Library, and Safari, all have a PERI of 30. While lower than the Admin Building, these values still represent a moderate ecological risk. The uniformity of these PERI values across multiple sites suggests that cadmium contamination is a widespread issue on the campus, albeit not as severe as at the School Park. These moderate PERI levels indicate that monitoring and possibly preventive measures are necessary to ensure that cadmium levels do not escalate, thereby preventing further environmental degradation.

Generally speaking, the findings from Table 5 emphasize the varying degrees of ecological risk across the campus, with the school park emerging as a priority for environmental intervention, while other areas require consistent monitoring to manage the moderate risks posed by cadmium pollution. The implications for environmental and public health management in this study are strongly supported by previous research on heavy metal contamination in urban and academic environments. In urban environments in Africa and Asia, where cadmium contamination is increasingly recognized as a public health concern, studies have emphasized the need for regular monitoring and management of contaminated sites (Okereke *et al.*, 2019). For example, research conducted in Nigeria by Afolabi *et al*. (2017) recommended regular monitoring of heavy metal concentrations in urban environments to prevent risks to public health. In this context, the findings from Kwara State University underscore the necessity of incorporating environmental monitoring into public health policy, particularly in areas with high potential for cadmium accumulation in both soil and plants. The proposed strategies for mitigating cadmium contamination, such as phytoremediation with hyperaccumulators like *Delonix regia*, align with global practices being implemented in areas with heavy metal pollution. Phytoremediation has been widely studied as a sustainable and cost-effective approach for remediating contaminated sites, particularly in areas with high levels of heavy metals like cadmium (Zhao *et al.,* 2019). The integration of phytoremediation strategies within the environmental management framework of the university could serve as a model for other similar institutions dealing with cadmium pollution.

Table 5. Potential Ecological Risk Index (PERI) of Cadmium (Cd)

S/N	Site	Ecological Risk Index of Cadmium (ERICd)
1.	KWASU Chapel	30
2.	HM	30
3.	Administrative Block	30
4.	School Park	60
5.	Library	30
6.	Safari	30

ERI<40: Low ecological risk; 40≤ERIi<80: Moderate ecological risk; 80≤ERIi<160: Considerable ecological risk; 160≤ERIi<320: High ecological risk; ERIi≥320: Very high

Conclusion: In conclusion, the findings from this study contribute to the expanding body of research on cadmium contamination in urban and academic environments. Similar to past studies, this research underscores the significant ecological and public health risks associated with cadmium contamination, particularly in areas with high bioaccumulation potential. The study reinforces the need for regular environmental monitoring, targeted remediation strategies, and public health campaigns to address the risks posed by cadmium contamination. By building on lessons learned from past research, Kwara State University can implement effective interventions to mitigate the impact of cadmium pollution on both the environment and public health.

REFERENCES

Adewale, OM; Olayanju, TM; Lawal, AO (2021). Assessment of Heavy Metal Contamination in Urban Soils and Crops: A Case Study in Ilorin, Nigeria." *Environ. Monit. Assess.* 193(6), 1-12.

Afolabi, OA; Adesope, OM (2017). Monitoring of heavy metal concentrations in urban environments: A focus on public health risks in Nigeria. *Env. Toxicol. Chem.*, 36(7), 1937-1945.

Alloway, BJ; Jackson, AP; Morgan, H (2017). The accumulation of cadmium by vegetables grown on soils contaminated from a variety of sources. *Sci. Tot. Environ.* 9: 233-235.

Chen, L; Luo, S.L; Li, XJ; Wan, Y; Chen, JL. Liu, CB (2014). Interaction of Cd-hyperaccumulator Solanum nigrum L. and functional endophyte Pseudomonas sp Lk9 on soil heavy metals uptake. *Soil Biol. Biochem*., 68, 300–308.

Crock, JG; Larison, JR; Gough, LP (2019). Cadmium accumulation in native vegetation of Alaska and Colorado. In: *Metals Biol.Med*., vol. 6. JA John Libbey Eurotext, Paris, pp. 177/179.

Ebong, GA; Akpan, MM; Mkpenie, VN (2008). Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by Carica papaya and Talinum triangulare in Uyo, Nigeria. *Environ. J.Chem.*, 5(2): 281-290.

Echem, O.G (2014). Determination of the levels of heavy metal (Cu, Fe, Ni, Pb and Cd) uptake of pumpkin (Telfairia occidentalis) leaves cultivated on contaminated soil. *J. Appl. Sci. Environ. Man.*, 18(1), 71-77.

Edogbo, B; Okolocha, E; Maikai, B; Aluwong, T; Uchendu, C (2020). Risk analysis of heavy metal contamination in soil, vegetables and fish around Challawa area in Kano State, Nigeria. *Sci. Afr.*, 7, Article e00281. https://doi.org/10.1016/j.sciaf.2020.e00281.

European Union (EU). (2019). Cadmium. EU Agency for Safety and Health at Work.

Ghosh, A.K.; Bhatt, M.A.; Agrawal, H.P. (2012). Effect of long term application of treated sewage water on heavy metal accumulation in vegetables grown in Northern India. *Environ. Mon. Assess.*, 184: 1025-1036.

Gochfeld, M(2020). Factors influencing susceptibility to metals. *Environ. Health Per.*, 105, 817/822.

Hakanson, L (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. *Wat. Res.*, 14: 975–1001.

Hossain, MAR; Ahmed, M; Ojea, E; Fernandes, JA (2018). Impacts and responses to environmental change in coastal livelihoods of south-west Bangladesh. pp50 generic. wordpress.soton.ac.uk.

International Agency for Research on Cancer (IARC). (2019). Cadmium and cadmium compounds. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.

Järup, L(2003). Hazards of heavy metal contamination. *Bri. Med. Bull.*, 68(1), 167-182.

Jawad, J. (2010). The Level of heavy metals in selected vegetables crops collected from Baghdad city markets. *Pak. J.Nut.*, 9(7): 683-685.

Kabata-Pendias, A (2001). Trace elements in soils and plants. 3d ed.CRC Press LLC, USA, 331.

Khan, MA.; Khan, S; Khan, A; Alam, M (2017). Soil contamination with cadmium, consequences and remediation using organic amendments. *Sci Total Environ*., 601–602:1591–1605. https://doi.org/10.1016/j.scitotenv.2017.06.030.

Lawal, A; Audu, A(2011). Analysis of Heavy Metals found in Vegetables from some Cultivated Irrigated Gardens in the Kano Metropolis. *Nig. J. Environ. Chem. Ecotox*., 3(6): 142-148.

Li, C; Zhou, K; Qin, W; Tian, C; Qi, M; Yan, X; Han, W (2019). A review on heavy metals contamination in soil: effects, sources, and remediation techniques. Soil and Sediment Contamination: An Intern. J., 28(4), 380-394.

McLaughlin, MJ; Zarcinas, BA; Stevens, DP; Cook, N (2019). "Soil testing for heavy metals," Communications in *Soil Sci. Pla. Anal*., (31) 11–14: 1661–1700.

Okereke, OA; Essien, E.B.; Wegwu, MO (2019). Heavy metals contamination in urban environments: Health risks and environmental management strategies. *J. Environ. Hea.*, 81(6), 47-56.

Sharma, P; Sharma, S (2019). Heavy metal contamination and phytoremediation: A review on cadmium and its hyperaccumulators. *Environ. Sci. Pol. Res.*, 26(2), 1246-1257.

Taiwo, AM; Adekola, MB; Olatunde, KA; Abdullahi, KL; Ogunkoya, PK; Lawal, ER; Adenekan, A; Avan, OJ; Jimoh, AO; Oladimeji, G (2021). Human health risk assessment of essential and non-essential metals in vegetables (Jute Mallow, Onions, Celosia, Spinach and Tomatoes) from Ogun, Lagos and Oyo states, southwestern Nigeria. *Vegetos,* 34, 390-403. https://doi.org/10.1007/s42535-021-00217-x.

United States Environmental Protection Agency (USEPA) (2011). Exposure factors handbook 2011.

Woldetsadik, K; Drechsel, P; Bernard, K; Fisseha, I; Gebrekidan, H(2020). Heavy metals pollution in urban soils of Africa and Asia: A review of public health implications and environmental management strategies. *Environ. Sci. Pol*, 107, 57-67.

World Health Organization (2019). Chemical Safety and Health, Avenue Appia, 1211 *Geneva* 27, Switzerland. WHO/CED/PHE/EPE/19.4.3.

Zhang, L; Zhu, G; Ge, X; Xu, G; Guan, Y (2018). Novel insights into heavy metal pollution of farmland based on reactive heavy metals (RHMs): pollution characteristics, predictive models, and quantitative source apportionment. *J. Haz. Mat.,* 360, 32-42.

Zhao, H; He, B; Wang, TY; Meng, J; Xiao, RB; Liu, SR; Zhou, YQ; Shi, B (2019). Pollution characteristics of heavy metals and source-sink relationship in typical city of the South China. *Acta Sci.* 39, 2231–2239