Bioaccumulation Potential and Phytochemical Profiling of *Coffea arabica* And *Pueraria montana* Leaves Obtained from Eyaa Community in Eleme Local Government Area of Rivers State, Nigeria

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.
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Abstract
This study investigated the phytochemical composition and metal content of Coffea arabica and Pueraria montana leaves collected from Eyaa Community, Eleme Local Government Area, Rivers State, Nigeria. Phytochemical screening was conducted using spectrophotometric methods, while metal content was determined with an atomic absorption spectrophotometer (AAS). The phytochemical analysis showed thatCoffea arabica contained higher concentrations of alkaloids (67.00 ± 0.01 mg/ml), polyphenols (11.03 ± 0.00 mg/ml), and tannins (0.99 ± 0.00 mg/ml), indicating its strong antioxidant and stimulant potentials. In contrast, Pueraria montana *exhibited elevated levels of flavonoids (30.00 ± 0.01 mg/ml), cardiac glycosides (27.01 ± 0.02 mg/ml), and puerarin (37.00 ± 0.01 mg/ml), suggesting pronounced antioxidant, anti-inflammatory, and cardioprotective properties.Soil metal analysis revealed the presence of iron (1.939 ± 0.01 mg/kg), copper (0.02 ± 0.00 mg/kg), nickel (0.005 ± 0.00 mg/kg), and lead (0.019 ± 0.00 mg/kg), while cadmium, arsenic, and chromium were not detected. Metal content analysis of the plant samples showed that* Pueraria montana *contained iron (20.692 ± 0.00 mg/kg), chromium (0.014 ± 0.00 mg/kg), and lead (0.115 ± 0.00 mg/kg), whereas* Coffea arabica *contained iron (1.846 ± 0.00 mg/kg), copper (0.021 ± 0.00 mg/kg), and nickel (0.006 ± 0.00 mg/kg). The findings indicate that* Pueraria montana *has a higher tendency to bioaccumulate metals such as chromium and lead from the soil. The study therefore recommends regular monitoring of heavy metal concentrations in medicinal plants to ensure their safety and suitability for therapeutic applications.*

Keywords: *Bioaccumulation, Phytochemicals, Heavy metals, Coffea arabica, Puerariamontana, Environmental pollution*

1. INTRODUCTION

Environmental contamination, particularly from heavy metals, poses serious ecological and public health challenges due to their persistence, non-biodegradability, and potential for bioaccumulation within biological systems [1]. Unlike organic pollutants that can degrade over time, heavy metals persist in the environment, cycling through soil, water, and living organisms for decades. They enter the ecosystem through both natural processes such as rock weathering and volcanic activity, and anthropogenic sources including industrial discharges, mining, agricultural runoff, and fossil fuel combustion. Once released, these metals can accumulate in sediments and vegetation, ultimately entering the food chain and posing risks to human and animal health. The ecological implications are far-reaching, leading to habitat degradation, biodiversity loss, and disruptions in biogeochemical cycles. Plants play a vital role as bioindicators and phytoremediators of such contamination through mechanisms such as phytoremediation, bioaccumulation, and detoxification, thereby maintaining ecosystem stability [2]. Their ability to absorb, translocate, and store toxic elements makes them valuable tools in monitoring environmental quality and restoring contaminated ecosystems. Through processes like phytoextraction, phytostabilization, and phytovolatilization, plants can either remove or immobilize heavy metals, reducing their bioavailability and environmental impact. Additionally, the physiological and biochemical responses of plants to metal exposure, such as antioxidant enzyme activation and chelation, serve as reliable indicators of pollution levels in terrestrial ecosystems.

Coffea arabica and *Pueraria montana* are two ecologically and economically important plant species known for their environmental adaptability and bioactive properties. *Pueraria montana* (commonly known as kudzu vine) belongs to the Fabaceae family and is a perennial climbing vine characterized by its rapid growth and invasive nature [3]. It can grow up to 20 meters per year and reach heights of about 30 meters where suitable support structures are available, allowing it to dominate large areas of vegetation. Native to East and Southeast Asia, this leguminous vine is valued for its medicinal and nutritional applications, as its tuberous roots are traditionally used as a source of starch and in herbal medicine [4]. Pharmacologically, it contains bioactive isoflavones such as puerarin, daidzein, and genistein, which exhibit antioxidant, anti-inflammatory, and estrogenic properties. Ecologically, *Pueraria montana* contributes to soil enrichment through nitrogen fixation, thereby improving soil fertility and stabilizing degraded lands. Its high biomass production and rapid metal uptake make it a promising species for phytoremediation studies. *Coffea arabica* (Arabica coffee), a member of the Rubiaceae family, is one of the most commercially significant coffee species worldwide and is widely cultivated for its high-quality beans [5]. It is the first coffee species to have been domesticated and accounts for approximately 60% of global coffee production [6]. Beyond its economic importance as a cash crop, *C. arabica* is rich in bioactive compounds, including alkaloids (such as caffeine), polyphenols, and flavonoids, which contribute to its antioxidant and stimulant effects [7]. These compounds not only define its pharmacological and sensory properties but also enhance its resistance to oxidative stress and metal-induced toxicity. In environmental research, *C. arabica* has gained attention for its potential to tolerate and accumulate trace metals from contaminated soils, suggesting its possible role as a bioindicator or phytoremediator species.

Heavy metals such as iron, copper, nickel, lead, and chromium are naturally occurring elements with significant biological and environmental implications. While essential metals like iron and copper play critical roles in physiological processes such as oxygen transport, enzyme activity, and cellular metabolism [8][9], their excessive accumulation can lead to toxicity and oxidative stress [10]. Elevated levels of these metals can interfere with enzymatic functions, generate reactive oxygen species (ROS), and damage cellular components including lipids, proteins, and DNA. Conversely, non-essential metals like lead and chromium are primarily toxic, causing severe environmental and health impacts even at low concentrations [11, 12]. Lead pollution, often derived from industrial emissions, mining, and agrochemicals, adversely affects both flora and fauna, leading to reduced seed germination, stunted growth, and impaired photosynthesis in plants [13]. Similarly, chromium toxicity, especially in its hexavalent form (Cr^{6+}), can cause respiratory, dermatological, and developmental defects in humans and animals, as well as growth inhibition and chlorosis in plants [14].

Eyaa community, located in Eleme Local Government Area of Rivers State, Nigeria, forms part of the Niger Delta industrial hub, an area characterized by intensive petrochemical, oil refining, and manufacturing activities. The region is notably susceptible to environmental degradation due to frequent industrial emissions, oil spills, and waste disposal practices. These activities increase the risk of heavy metal contamination in the soil, water bodies, and vegetation, posing a threat to both ecological balance and human livelihoods. The soils in Eleme and its environs often exhibit elevated concentrations of metals such as lead, cadmium, and nickel, which can be taken up by crops and medicinal plants cultivated in the area. Despite its ecological and economic relevance, there is limited scientific documentation on the extent of heavy metal bioaccumulation and phytochemical composition of local flora such as *Coffea arabica* and *Pueraria montana* within this environment. Therefore, this study aims to evaluate the phytochemical composition and metal content of *Coffea arabica* and *Pueraria montana* leaves obtained from Eyaa community, Eleme LGA, Rivers State. The specific objectives are to:(i) identify and quantify the phytochemical constituents of both plants; (ii) determine the concentration of selected heavy metals in the plants and surrounding soil; and (iii) assess their potential for metal bioaccumulation and associated health implications. This investigation will provide baseline data for environmental monitoring and contribute to the understanding of plant-based remediation strategies suitable for industrially impacted ecosystems in the Niger Delta region.

2. MATERIALS AND METHODS

2.1. Description of the Study Area (Eyaa Community)

Eyaa community is located within Eleme Local Government Area (LGA) of Rivers State, in the Niger Delta region of southern Nigeria [15]. Geographically, the community lies approximately between latitude 4°46′N and 4°50′N and longitude 7°06′E and 7°10′E, placing it within the humid tropical zone of West Africa [16]. The area is part of the extensive Niger Delta plain characterized by low-lying terrain, swampy landscapes, and an intricate network of creeks and rivers that drain into the Atlantic Ocean [17].The climate of Eyaa is typically tropical monsoonal, marked by a distinct wet and dry season [18]. The wet season spans from March to October, with annual rainfall ranging between 2,000–2,500 mm, while the dry season occurs from November to February, often influenced by the northeast trade wind known as the Harmattan [19]. Average temperature fluctuates between 26°C and 32°C, and relative humidity remains consistently high, typically above 75% throughout the year [20, 26]. These climatic conditions support dense vegetation, comprising predominantly tropical rainforest species, grasses, and shrubs [21, 26].The soil profile of Eyaa consists mainly of sandy loam and clayey alluvial deposits, which, while fertile, are susceptible to contamination due to high permeability and surface runoff from surrounding industrial zones [22]. The topography is relatively flat, with an elevation generally below 50 meters above sea level, predisposing the area to seasonal flooding, especially during peak rainfall periods [23].

Eyaa forms part of the Eleme industrial corridor, which hosts several petrochemical, fertilizer, and refinery complexes, including those operated by major oil and gas industries [24]. Prolonged industrial activity, coupled with inadequate waste management practices, has resulted in environmental stressors such as soil and water pollution, air quality deterioration, and heavy metal accumulation in agricultural lands and vegetation [25]. The community is also traversed by minor access roads and drainage channels that connect to larger industrial settlements such as Onne and Alesa.

Figure 1: A map showing the geographical location of Eyaa Community, the sampling points, and its surrounding communities

Economically, the inhabitants of Eyaa engage primarily in subsistence farming, fishing, and small-scale trading, relying heavily on local natural resources for their livelihoods [15]. Common crops cultivated include cassava, maize, and vegetables, alongside several medicinal and wild plant species such as *Coffea arabica* and *Pueraria montana* [20]. The dependence of the local population on these plants for food, traditional medicine, and ecological functions makes it crucial to assess their quality and safety in the face of increasing industrial pollution [25]. Eyaa community presents a typical example of an industrial–agricultural interface ecosystem in the Niger Delta, where environmental contamination and human livelihood are closely intertwined [16]. Its geographical location, climatic characteristics, and anthropogenic activities make it a strategic site for evaluating the impact of heavy metal contamination on local flora and for investigating the phytoremediation potential of native and cultivated plant species [19].

2.2. Leaf Sample collection

Fresh, mature, and disease-free leaves of *Pueraria montana* (kudzu vine) and *Coffea arabica* (coffee plant) were carefully collected from different locations within Eyaa community, situated in Eleme Local Government Area (LGA) of Rivers State, Nigeria. Sampling was conducted during the early morning hours to minimize physiological stress on the plants and to prevent degradation of heat-sensitive metabolites. Leaf samples were collected from at least five different points within the community to ensure representativeness of the area and to account for spatial variability in environmental conditions and contamination levels. The sampling sites included areas close to farmlands, residential zones, and locations within proximity to industrial effluent discharge routes and drainage channels. For each species, approximately 10–15 fully expanded leaves were collected per sampling point using clean stainless-steel scissors and gloves to prevent cross-contamination. The samples were immediately placed into sterile, clearly labeled polyethylene bags and transported in ice-cooled containers to the laboratory for further processing. All tools used during the collection process were rinsed thoroughly with distilled water and ethanol between samples to avoid metal carry-over. Metadata such as GPS coordinates, habitat description, proximity to possible pollution sources, and surrounding land use were recorded for each sampling point. The collected specimens were taxonomically identified and authenticated by a botanist at the Department of Plant Science and Biotechnology, University of Port Harcourt, Nigeria. Voucher specimens were prepared and deposited in the departmental herbarium for reference and future studies. This rigorous sampling protocol ensured that the plant materials obtained were of analytical quality, adequately representative of the local environmental conditions, and suitable for subsequent analyses involving heavy metal bioaccumulation and phytochemical profiling.

2.3. Leaf Sample Preparation

The collected fresh leaves of *Pueraria montana* and *Coffea arabica* were first subjected to thorough cleaning to ensure the removal of extraneous materials and potential surface contaminants. Each leaf sample was gently rinsed with tap water to eliminate adhering soil particles and debris, followed by successive washing with deionized water to remove residual impurities and dust. This process ensured that only intrinsic constituents of the plant material were analyzed, minimizing the risk of exogenous contamination from the environment. After washing, the leaves were spread evenly on clean trays and air-dried under shade at ambient room temperature (approximately 25–28°C) for five days. Shade-drying was preferred over oven-drying to prevent the degradation of thermolabile phytochemicals and to preserve the natural composition of bioactive constituents. The drying process continued until the samples attained a constant weight, indicating the complete removal of moisture. The dried leaves were subsequently ground into a fine powder using a clean, high-speed electric blender (Model BX 300, Germany). The powdered samples were sieved through a 2 mm mesh to achieve uniform particle size, ensuring homogeneity for analytical consistency. Between each grinding session, the equipment was cleaned with ethanol and dried to avoid cross-contamination between species. The powdered samples were stored in airtight amber glass containers, labeled appropriately, and kept in a cool, dry place until extraction.

2.4. Leaf Sample Extraction

For extraction, two hundred grams (200 g) of each powdered sample was accurately weighed using a digital analytical balance (±0.001 g precision). The measured powders were soaked separately in 1000 ml of distilled water in sterile conical flasks, sealed, and left to macerate for 72 hours at room temperature with intermittent agitation to enhance solvent penetration and solute diffusion. The macerated mixtures were then filtered using Whatman No. 1 filter paper to remove insoluble residues and obtain a clear aqueous extract. The resulting filtrates were concentrated using a rotary evaporator (Model RE-52A, Shanghai, China) at a controlled temperature of 60°C under reduced pressure to remove excess solvent without damaging heat-sensitive compounds. The concentrated extracts were further dried to a semi-solid form and stored in sterile glass vials under refrigeration (4°C) until required for heavy metal and phytochemical analyses. This standardized preparation procedure ensured the production of clean, reproducible plant extracts suitable for accurate determination of bioaccumulated metals and secondary metabolites.

2.5. Soil sample collection

Composite soil samples were collected from Eyaa community, located in Eleme Local Government Area (LGA) of Rivers State, using a clean stainless-steel soil auger. The auger was driven to a depth of approximately 20 cm to obtain representative topsoil samples, as this layer typically accumulates the highest concentration of contaminants and nutrients. The collected soil samples were immediately transferred into sterile, airtight polyethylene tubes, properly labeled to indicate sampling location and depth, and then sealed to prevent moisture loss and external contamination. The samples were subsequently transported to the laboratory for further physicochemical and heavy metal analyses under controlled conditions.

2.6. Soil Sample Preparation

The collected soil samples were air-dried at room temperature in the laboratory to eliminate residual moisture and facilitate homogenization. The dried samples were gently disaggregated and passed through a 2 mm stainless-steel sieve to obtain a uniform particle size and remove coarse debris such as stones, roots, and organic matter. The sieved samples were stored in clean, labeled containers prior to digestion to prevent contamination and ensure sample integrity.

2.7. Soil Sample Digestion

For digestion, 0.5 g portions of the prepared soil samples were accurately weighed in triplicate using an analytical balance with a precision of ±0.001 g. Each portion was transferred into a clean digestion flask and treated with 20 ml of freshly prepared aqua regia (a 3:1 mixture of concentrated hydrochloric acid, HCl, and nitric acid, HNO_3). The mixtures were heated in a fume cupboard for approximately 2 hours at a moderate temperature until the solutions became clear, indicating complete dissolution of the sample matrix. After cooling, the digests were filtered through Whatman No.1 filter paper into 50ml volumetric flasks to remove any remaining particulates. The filtrates were then diluted to the mark with distilled water, producing clear analytical solutions suitable for subsequent heavy metal determination using Atomic Absorption Spectrophotometry (AAS). This standardized digestion process ensured consistency, minimized contamination, and enabled accurate quantification of heavy metal concentrations in the soil samples.

2.8. Determination of Bioaccumulated Metals

Instrumentation

The concentrations of selected heavy metals in digested soil and plant samples were determined using Atomic Absorption Spectrophotometry (AAS) (Model: *novAA 800 Dmodel from Analytik Jena*). Element-specific hollow cathode lamps were used for each metal at their respective analytical wavelengths. Calibration curves were established using five-point standard solutions prepared from certified stock standards, covering the expected concentration range for each element. Instrumental parameters such as slit width, lamp current, burner height, and fuel flow rate were optimized according to the manufacturer's recommendations to ensure analytical accuracy and precision.

2.9. Quality Control and Assurance

To ensure analytical reliability, reagent blanks and calibration verification standards were included in each analytical batch. Multi-element calibration standards were prepared from certified stock solutions, and calibration linearity was maintained at $R^2 \geq 0.995$. All analyses were performed in triplicate, and results were expressed as mean ± standard deviation (SD). The accuracy of the analytical procedure was evaluated using spike recovery tests and analysis of certified reference materials (CRMs) where available. Acceptable recovery values ranged between 85–115%**,** while relative standard deviations (RSD) of replicate analyses remained below 10%**.** The limit of detection (LOD) and limit of quantification (LOQ) for each metal were determined from replicate blank analyses using standard statistical methods.

2.10. Phytochemical Screening

Qualitative Phytochemical Screening Test

Qualitative screening of phytochemicals in both *Pueraria Montana* and *Coffea arabica* were done in Rivers State University, Biochemistry laboratory, using standard procedures.

Test for Alkaloid:2ml of the extract was mixed with 5 drops of Mayer's reagent. The formation of white precipitate indicated the presence of alkaloids.

Test for Flavonoids (Shinde's Test): 2ml of the extract was mixed with 5 drops of concentrated Hydrochloric acid and Magnesium turning were added and heated for 5 minutes. The presence of red colour indicated the presence of flavonoids.

Test for polyphenols: 2ml of the extract and 5 drops of ferric chloride solution was delivered into a Test tube. Bluish green formation upon gentle swirling indicated the presence of polyphenols.

Test for saponins: 2ml of the extract was mixed with 2ml of deionized water and gently Shaked. Froth formation indicated the presence of saponins.

Test for steroids (Libermann-Burchard test): 2ml of the extract, 5 drops of chloroform, 4 drops of acetic anhydride, 1 drop of concentrated sulphuric acid were mixed in a Test tube. Development of purple colour which later changed to blue indicated the presence of steroids.

Test for tannins: 2ml of the extract was mixed with 2ml of lead acetate solution. White precipitate was formed indicating the presence of tannins.

Test for Cardiac glycoside: The extract was mixed with Anthrone reagent on a watch glass. A drop of concentrated sulphuric acid was added into a paste and warmed gradually over water bath. Formation of a dark green colour indicated the presence of cardiac glycoside

Test for Carotenoids: 2ml of the extract, 2ml of chloroform and 3ml of sulphuric acid was mixed to form layer. A reddish-brown colour indicated the presence of carotenoids.

Test for Terpenoids (Shinde's Test): 2ml of the extract was mixed with 5 drops of concentrated Hydrochloric acid and Magnesium turning were added and heated for 5 minutes. The presence of red colour indicated the presence of terpenoids.

Test for phenols: 2ml of the extract and 5 drops of ferric chloride solution was delivered into a Test tube. Bluish green formation upon gentle swirling indicated the presence of polyphenols.

Test for puerarin (Shinde's Test): 2ml of the extract was mixed with 5 drops of concentrated Hydrochloric acid and Magnesium turning were added and heated for 5 minutes. The presence of red colour indicated the presence of Puerarin

Quantitative Phytochemical Screening Test

The spectrophotometer was used to quantify the phytochemical constituents of the plants in accordance with ISO 17025.

2.11. Data analysis

The data obtained from the Atomic Absorption Spectrophotometry (AAS) and other analytical procedures were statistically evaluated using the Statistical Package for the Social Sciences (SPSS), version 30.0. Descriptive statistics, including the mean and standard deviation, were employed to interpret the results.

3. RESULT

Table1: Qualitative Phytochemical screening of *Coffea arabicaand Pueraria montana*

S/N	Components	*Coffea arabica*(mg/ml)	*Pueraria montana*(mg/ml)
1	Flavonoid	++	+++
2	Polyphenol	++	-
3	Saponins	-	+
4	Tannins	-	-
5	Cardiac glycoside	+	++
6	Alkaloids	+++	+++
7	Terpenoids	+	-
8	Phenol	-	-
9	Steroids	-	-
10	Carotenoids	-	-
11	Puerarin	-	+++

Key: +++ = Absolutely detected, ++ =Moderately detected, + = Detected
- Not detected

Table 2: Quantitativephytochemical screening of *Coffea arabicaand Pueraria montana*

S/N	Components	*Coffea arabica*(mg/ml)	*Pueraria Montana*(mg/ml)
1	Flavonoid	12.01±0.05	30.00±0.01
2	Polyphenol	11.03±0.00	-
3	Saponins	-	6.7±0.00
4	Tannins	0.99±0.00	-
5	Cardic glycoside	7.00±0.02	27.01±0.02
6	Alkaloids	67.00±0.01	55.67±0.01
7	Terpeniods	2.00±0.00	-
8	Phenol	1.69±0.02	-
9	Steroids	-	-
10	Carotenoids	-	-
11	Puerarin	-	37.00±0.01

The values are in triplicate of mean ± SD.

Table 3: Metals concentration in (mg/kg) of composite Soil Sample obtained from Eyaa

METALS (Mg/Kg)	SOIL SAMPLE	WHO STANDARDS (2009)	NESREA STANDARD (2011)
Fe	1.939±0.01	425.3	1000
Cu	0.021±0.00	100.0	100
Cd	ND	3.0	5
As	ND	20.0	10
Cr	ND	100.0	50
Ni	0.005±0.00	50.0	20
Pb	0.019±0.00	2.3	100

The values are in triplicate of mean ± SD.

Table 4: Comparative Metals concentration in (mg/ml) of *Coffea arabica* and *Pueraria montana* extract obtained from Eyaa community

Metals (mg/kg)	***Puereria montana***	***Coffea arabica***	**WHO standards (2009)**	**NESREA Standard (2011)**
Fe	20.691±0.00	1.486±0.00	425.3	10
Cu	ND	0.021±0.00	10	1.0
Cd	ND	ND	0.1	0.05
As	ND	ND	0.2	0.1
Cr	0.014±0.00	ND	0.2	0.5
Ni	ND	0.006±0.00	0.5	0.5
Pb	0.115±0.00	ND	0.1	0.1

The values are in triplicate of mean±SD.

4. DISCUSSION

The results presented in Table 1 indicate that flavonoids, cardiac glycosides, and alkaloids were detected in both *Coffea arabica* and *Pueraria montana*. Polyphenols and terpenoids were found only in *Coffea arabica*, whereas saponins and puerarin were exclusive to *Pueraria montana*. Bioactive compounds such as tannins, phenols, steroids, and carotenoids were not detected in either plant species. Phytochemicals are biologically active, naturally occurring compounds found in plants that provide health benefits beyond those derived from macronutrients and micronutrients [27]. These compounds accumulate in various parts of plants, including roots, stems, leaves, flowers, fruits, and seeds. Flavonoids are polyphenolic compounds that are widely distributed in nature. More than 4,000 types of flavonoids have been identified, many of which occur in vegetables, fruits, and beverages such as tea, coffee, and fruit juices [28]. Flavonoids have attracted significant attention due to their diverse biological and pharmacological properties. In this study, flavonoids were moderately detected in *Coffea arabica* (12.01 ± 0.05) and highly detected in *Pueraria montana* (30.00 ± 0.01). The higher flavonoid content in *Pueraria montana* suggests that the plant may offer better protection against certain diseases, including cardiovascular disorders, cancer, and neurodegenerative diseases, compared to *Coffea arabica*. This finding aligns with the report of Nwachoko et al. [29, 42], who observed that plants such as *Anthocleista vogelii* are rich in flavonoids.

Alkaloids are naturally occurring compounds containing heterocyclic nitrogen atoms and are generally basic in nature [28, 42]. They are biosynthesized by a wide range of organisms, including plants, animals, fungi, and bacteria. Alkaloids are typically characterized by their bitter taste, with quinine being one of the most intensely bitter substances known [30, 42]. In this study, alkaloids were abundantly present in both *Pueraria montana* (55.67 ± 0.01) and *Coffea arabica* (67.00 ± 0.01). Alkaloids are known for their therapeutic and pharmacological activities, implying that the high alkaloid concentrations observed in these plants underscore their medicinal value and potential for use in traditional medicine for treating various ailments. Cardiac glycosides are secondary metabolites synthesized by certain plants. In this study, cardiac glycosides were detected in *Coffea arabica* (7.00 ± 0.02) and moderately detected in *Pueraria montana* (27.01 ± 0.02). These compounds have been reported to enhance the force of heart contractions [31]. The detection of cardiac glycosides, particularly in *Pueraria montana*, suggests that extracts from this plant could be valuable in developing drugs for cardiac protection.

In this study, the concentrations of heavy metals in soil samples obtained from Eyaa community, Rivers State, were analyzed. The metals assessed included iron (Fe), copper (Cu), cadmium (Cd), arsenic (As), chromium (Cr), nickel (Ni), and lead (Pb). Among these, cadmium, arsenic, chromium, nickel, and lead are non-essential metals, while iron and copper are essential elements required in trace amounts for plant metabolism. The results of the soil analysis revealed the presence of iron (1.939 ± 0.01 mg/kg), copper (0.021 ± 0.00 mg/kg), nickel (0.005 ± 0.00 mg/kg), and lead (0.019 ± 0.00 mg/kg). The concentrations of all the detected metals were below their respective permissible limits (425.3, 100, 50, and 2.3 mg/kg). These findings suggest that the soil from Eyaa community is within acceptable environmental safety levels for heavy metal contamination and poses minimal risk for phytotoxicity or bioaccumulation in plants. Heavy metal contamination in soils has become a major global concern over the past decades due to its detrimental environmental and health impacts [32]. Plants cultivated in contaminated soils can bioaccumulate heavy metals, thereby posing potential health risks to humans through the food chain [33].

Iron (Fe) is an essential mineral vital for numerous biological functions, including oxygen transport, electron transfer, and hemoglobin synthesis in humans [34]. Iron deficiency can result in anemia, chronic fatigue, irritability, hair loss, eye defects, and prolonged bleeding disorders. In this study, iron was found at a lower concentration in the soil samples compared to the limit recommended by the World Health Organization (WHO). The reduced iron concentration observed may be attributed to the soil pH, as extremely acidic or alkaline conditions are known to reduce the bioavailability of iron for plant uptake [35].Lead (Pb) forms complexes with oxo-groups in enzymes involved in hemoglobin synthesis and porphyrin metabolism [36]. Lead is a toxic heavy metal with no known biological role and is recognized as a major public health concern, capable of inducing toxicity at concentrations as low as 10 µg/kg [37]. In this study, the concentration of lead in the soil samples was below the WHO permissible limit of 2.3 mg/kg. The low lead level observed may be due to controlled industrial operations and proper management of lead-containing waste such as batteries and electronic devices in the study area [36]. These findings contrast with those of Greany et al. [38], who reported elevated lead levels above the WHO permissible limits in soil samples from industrial areas.

The analysis of metal content in plant samples revealed that only iron was detected in both *Coffea arabica* and *Pueraria montana*. Copper (Cu) and nickel (Ni) were found exclusively in *Coffea arabica*, while chromium (Cr) and lead (Pb) were detected only in *Pueraria montana*. Cadmium (Cd) and arsenic (As) were not detected in either plant species. All detected metals were below permissible limits except lead in *Pueraria montana*, which exceeded the safe threshold. Iron is an essential micronutrient for plants and plays a vital role in key physiological and biochemical processes such as photosynthesis, respiration, and enzymatic activity [35]. The low iron concentration observed in *Coffea arabica* may be linked to variations in soil properties and environmental conditions affecting metal uptake. Interestingly, *Pueraria montana* was found to accumulate toxic metals such as chromium and lead, suggesting that the species possesses the ability to absorb and remove non-essential metals from the soil. This ability indicates its potential application in phytoremediation, the use of plants to clean up heavy metal–contaminated soils. Rizwan et al. [39] reported that heavy metal uptake by plants reduces soil toxicity, thereby creating a more favorable environment for other organisms and vegetation.

Bioaccumulation refers to the process by which organisms absorb and retain substances such as heavy metals at a rate faster than they can excrete or metabolize them [40]. In this study, *Pueraria montana* exhibited higher concentrations of metals such as iron (20.691 ± 0.00 mg/kg), chromium (0.014 ± 0.00 mg/kg), and lead (0.115 ± 0.00 mg/kg) compared to their respective concentrations in the soil (1.939 ± 0.01, 0.00 ± 0.00, and 0.019 ± 0.00 mg/kg). According to Ali et al. [41], a higher concentration of heavy metals in plant tissues compared to the surrounding soil is an indication of bioaccumulation capacity. Therefore, the elevated chromium and lead levels recorded in *Pueraria montana* suggest that the plant has significant bioaccumulation potential, making it a suitable candidate for the phytoremediation of contaminated environments. With heavy metal accumulation in *Pueraria montana,* it may also not be beneficial to be used for therapeutic purposes.

5. CONCLUSION

The phytochemical analysis revealed that both *Coffea arabica* and *Pueraria montana* contain significant bioactive compounds such as flavonoids, alkaloids, and cardiac glycosides, which are well recognized for their therapeutic potentials. The heavy metal assessment indicated the presence of iron, copper, nickel, and lead in the soil samples. Specifically, copper and nickel were detected exclusively in *Coffea arabica*, while chromium and lead were identified only in *Pueraria montana*. Furthermore, the concentrations of chromium and lead were higher in the plant tissues than in the surrounding soil, suggesting that *Pueraria montana* possesses a strong capacity for bioaccumulation of these metals. Although the concentrations of all detected metals were within permissible limits, their presence in medicinal plants remains a public health concern due to the potential risk of metal accumulation in humans through prolonged consumption. Consequently, this study emphasizes the importance of continuous monitoring of heavy metal levels in medicinal plants to ensure their safety and suitability for therapeutic applications.

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