Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

Evaluating Phytoremediation Potential benchmarks of Medicinal Plants from Ashanti and Eastern Regions of Ghana.

Kofi Sarpong

Department of Chemistry Education,
Akenten Appiah-Menka University of Skills Training and Entrepreneurial Developmet,
Asante Mampong

Abstract

Phytoremediation which is the process of applying plants to extract pollutants from the ecosystem has gained popularity as a possible antidote for cleaning up vicinities since it offers a cost-effective and environmentally friendly treatment.This study supplies benchmarks for hazardous metals (lead, arsenic, copper, cadmium and mercury) depending on extensive assessment of plant variety and effectiveness indicators.Niton XL3 GOLDD+ X-ray fluorescence (XRF) was used to analyze the soils for the presence of hazardous metals (Pb, As, Cu and Cd) while levels (Pb, As, Cu and Cd) in medicinal plants were analyzed using VARIAN SPECTRA AA220 Zeeman Atomic Absorption Spectrometer (AAS) (Varian Canada Inc.). Mercury determination was by Atomic Absorption Spectrometry employed in the RA-915M Zeeman mercury analyzer (Lumex, St. Petersburg, Russia). Soil samples gathered from sites in Ashanti Region manifested mean concentrations of 4.39, 4.85, 11.66, 6.69 and 0.0474 for Pb, As, Cu, Cd and Hg respectively whereas that of Eastern Region had 3.39, 6.40, 13.44,6.02 and 0.06 for Pb, As, Cu, Cd and Hg respectively. The mean soil metal concentrations were below World Health Organization Maximum Permissible Limits (WHO/MPL) for the respective metals. About thirty-eight medicinal plants samples were analyzed. Levels of Pb, As, Cu, Cd evaluated in medicinal plants were below WHO MPL for the respective metals except that of Hg which possessed concentrations above WHO MPL. The translocated factor (TF), bioconcentration factor (BCF) and bioaccumulated coefficient (BAC) were calculated.The range of TF, BCF and BAC were: TF [Ashanti: $TF_{(Ashanti,\ Pb)}$ = (BDL-1.20), $TF_{(Ashanti,\ As)}$ = (0.78-3.87),$TF_{(Ashanti,\ Cu)}$ = (1.07-2.11), $TF_{(Ashanti,\ Cd)}$ = 0.13-11.88) and $TF_{(Ashanti,\ Hg)}$ = 0.61-1.69); Eastern: $TF_{(Eastern,\ Pb)}$ = (BDL-12.62), $TF_{(Eastern,\ As)}$ = (0.20-4), $TF_{(Eastern,\ Cd)}$ = (0.15- 36.30) and $TF_{(Eastern,\ Hg)}$ = BDL-13.17); BCF [Ashanti: $BCF_{(Ashanti,\ Pb)}$ = (BDL- 0.22), $BCF_{(Eastern,\ As)}$ = (0.11- 0.32), $BCF_{(Eastern,\ Cu)}$ = (0.01- 0.11), $BCF_{(Eastern,\ Cd)}$ = (BDL-0.03) and $BCF_{(Eastern,\ Hg)}$= (0.53-2389.41) and BAC [Ashanti: $BAC_{(Ashanti,Pb)}$ = (BDL- 0.14), $BAC_{(Ashanti,\ As)}$ = (0.04-0.65), $BAC_{(Ashanti,Cu)}$ = (BDL-0.07), $BAC_{(Ashanti,Cd)}$ = BDL-0.20) and $BAC_{(Ashanti,Hg)}$ = (2.01-191.70); Eastern: $BAC_{(Eastern,Pb)}$ (BDL-0.26), $BAC_{(Eastern,As)}$ = (BDL-0.62), $BAC_{(Eastern,Cu)}$ = (BDL-1.05), $BAC_{(Eastern,Cd)}$ = (BDL-0.04) and $BAC_{(Eastern,Hg)}$ = (BDL- 97.15). Calculated TF values showed that most of the medicinal plants from Ashanti Region exhibited high phytoextractive potential for As [3(60%) Ashanti Region > 8(53%) Eastern Region], Cu[(All,100%) Ashanti Region > 6(40%) Eastern Region], Cd [3(60%) Ashanti Region >

4(27%) Eastern Region] and Hg[2(40%) Ashanti Region > 4(27%) Eastern Region] than those of Eastern Region except that of Pb. Computed BCF values demonstrated medicinal plants from the two regions had phytooextractive potential for only Hg. Estimated BAC contents of medicinal plants from Ashanti Region all had phytoextractive potential for only Hg contrary to Eastern Region plants which had 5(15%) phytoextractive potential for only Hg. The medicinal plants from the two regions could serve as phytostabilizers for Hg.There occurred no significance difference in TF, BCF and BAC of medicinal plants from both Ashanti and Eastern Regions.

Keywords: Phytoremediation, Hazardous metals, Translocation factor, Bioaccumulation factor, Bioconcentration factor, Phytoextractive potential

1. Introduction

Anthropogenic activities produce extremely large quantities of pollutants including heavy metals into the ecosystem (Hameed et al., 2020). Despite the fact that selected pollutants exist naturally, human activities greatly increase their spread and accumulation in soil, water, and organisms. Sources such as mining activities, application of agriculture chemicals, indiscriminate disposal of e-waste to the environment, industrialization, urbanization, may contribute to the soaring concentrations of Potential Toxic Elements (PTE's) in the ecosystem.The PTE's adversely affect the ecosystem and human health, highlighting the urgent need to identify sources, understand impacts and develop effective solutions for a sustainable future (Nieder & Benbi, 2023). The PTE's such as cadmium (Cd), lead (Pb), arsenic (As), nickel (Ni), chromium (Cr), mercury (Hg), copper (Cu), etc. pose risks to human health and the environment when occurring beyond World Health Organization (WHO) / Food and Agricultural Organization (FAO) Maximum Permissible Limits (MPL) for heavy metals. High levels of heavy metals like Pb, As, Hg and Cd have toxic effects on the health of humans when consumed (Sarpong, 2025). These aforementioned harmful metals affect the kidneys and liver of humans at levels beyond permissible limits (Sarpong, 2025). For instance chronic exposure to Cd cause kidney damage resulting into kidney failure and may also lead to liver damage (Kim et al., 2021). Lead adversely affects the reproductive systems and cause brain damage in humans (Leon & Pacheco, 2020; WHO, 2024). Exposure of humans to excessive amounts of heavy metals are linked to Alzheimer, Parkinson's, vision impairment, dementia, etc (Li et al., 2019). Arsenic and Cr create cancers (Martinez et al., 2011; Braver-Sewrad et al., 2021). High exposure levels of Hg can also lead to liver damage (Rana et al., 2018). The heavy metals adversely affect the environment. For instance Hg upon entry into the environment through disintegration of rocks and from volcanic processes pollute water and soil and the entire environment (Natasha et al.,2020).Mercury may be absorbed into plants by means of the root hairs.Upon absorption most of the element remains in the roots while few is transferred to other organs of the plant. It adversely affects the plants at minimal levels and retards plant growth (Ahammad et al., 2018). Mercury also retards photosynthesis (Assad et al., 2016). Heavy metals can be toxic to hydrobiota resulting to death of species, contaminating aquatic ecosystems bringing about poor water quality,biomagnification,etc.

Due to problems contaminated areas pose to biota, various methods are applied to decontaminate such areas. Among the methods applied are: biological methods (bioremediation i.e. using microorganisms to bre ak down / immobilize metal contaminants and phytoremediation i.e. applying plants to extract, stabilize, or change, heavy metals in soil), physical methods (soil vapour extraction, soil washing and thermal desorption) (Lee et al., 2021) and chemical methods (in situ chemical oxidation, in situ chemical reduction and chemical stabilization), etc.Since physical methods such as removal of soil disturbs the environment, relocation of wildlife and human population, regeneration of large quantities of contaminated waste and so on, better methods must be sought. The method must be eco-friendly, applicable to decontaminate a wide range of PTE's over large areas and cost-effective. It must be able to transform toxic chemicals into less deleterious ones. It should not demand expensive equipments in its operation. The aforementioned methods may be applied to extract metals from areas contaminated with, Pb, Cd, As, Hg, Cr, etc. Phytoremediation method meets the conditions mentioned. Plants employed for phytoremediation procedure may be a hyperaccumulator (specialized plants that can remove and concentrate extraordinarily high levels of specific metals in their tissues—often 100-1000 times higher than normal plants without showing symptoms of toxicity) (Kramers, 2010). Examples of hyperaccumulators and metals they can extract are written against it: *Pteris vittata* (Zn), *Brassica juncea* (Pb), *Alysum murale* (Ni), *Chromolaena odorata* (Zn and Cd).

Medicinal plants like other plants have the tendency to absorb minerals and other nutrients from the soil. In addition, they absorb heavy metals which most are of no importance to living organisms. The medicinal plants are of immense benefits to living organisms (humans and animals) since they possess phytoconstituents with therapeutic characteristics. The tendency of these medicinal plants to absorb and accumulate metals by way of translocation factor (TF), bioconcentration factor (BCF) and bioaccumulation coefficient were explored to ascertain the phytoextractive benchmarks of selected medicinal plants from Ashanti and Eastern Regions which served as medicinal plants harvesting sites. Also it would be established if the plants were hyperextractor, phytostabilizer, etc.

MATERIALS AND METHODS

Study Areas

Gathering of samples took place at fifteen (15) sites in two regions namely Ashanti and Eastern.From Ashanti and Eastern regions seven (7) and eight (8) sites respectively were involved. Sites in Ashanti region included: Ejura (7˚23'0" N, 1˚22'0" W), Ayeduase - Kumasi (6˚40'0"N,1˚ 34'0"W), Asante - Mampong (7˚4'0" N, 1˚24' 0" W), Konongo (6˚37'0" N,1˚13'0" W), Donaso – Ejisu (6˚37'0" N,1˚13'0" W), Kumawu (6˚37'0" N,1˚13'0" W) and Tafo - Kumasi (6˚37'0" N,1˚13'0" W) whilst that of Eastern region were: Adawso (6˚31' 5.6532" N, 0˚16' 12.7956" W), Nkawkaw (6˚32'44.664" N, 0˚45'46.0368" W) situated in Kwahu West Municipal, Kwahu-Bepong (6˚ 36'N 0˚ 43'W/6.600˚ N 0.717˚W) and Kwahu-Asakraka (6˚37' 0" North, 0˚41'0" West) were all located in Kwahu South district, Bukuruwa (6° 40' 0" North, 0˚ 42' 0" W 0.750˚W), Kwahu-Kotoso, Kwahu-Ankoma and Kwahu - Tafo all on coordinates (6° 40'N 0˚45W/6.667˚N) in Kwahu East District. The map of the sampling areas were as indicated in the Figure 1.

Farming activities such as growing of crops were embarked upon in the sampling sites. During these activities inorganic fertilizers containing elevated amounts of Cd, Pb and As were applied to the crops to boost yield. Also micronutrient fertilizers possessing low quantities of Cu were added to the soil.

Fertilizers containing low amounts of Cd were added. Heavy metals in the environment might be absorbed by the crops. The crops were protected through the use of pesticides containing As (arsenic trioxide and lead arsenate), fungicides possessing Cu (copper oxychloride), and so on. The existence of these heavy metals cause soaring of those toxic metals in the vinicity.Heavy metals in sites near urban towns such as those in Kumasi arose from industrial origins (Akoto et al., 2017). Also illegal mining activities were embarked upon closer to some of the sites,

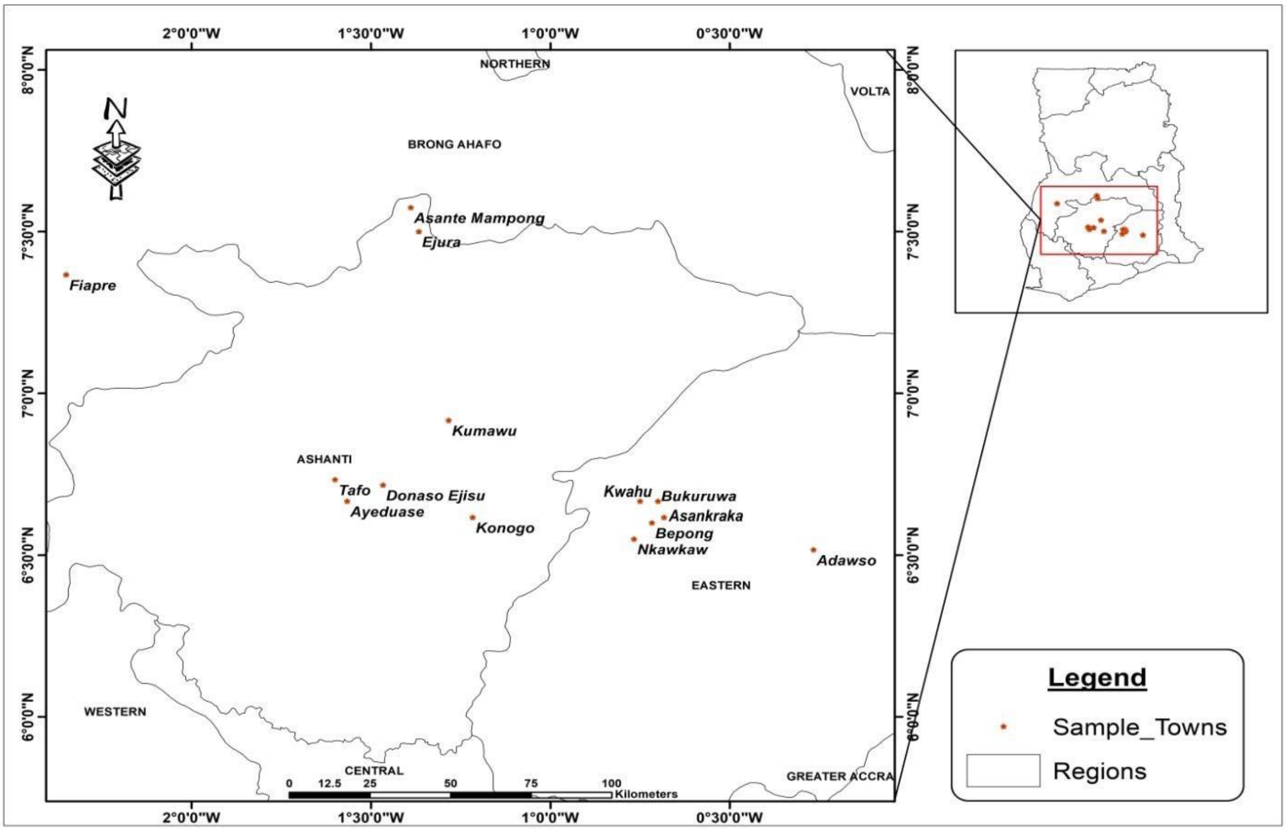

Figure 1: Map showing Areas of study (Sarpong,2025).

The medicinal plants of interest gathered, family, parts of plant and ethnomedical uses were as indicated in Table 1.

Table 1 Medicinal Plants Used in the Study

Name of Medicinal Plant	Family	Parts of Used	Ethno-medical uses
Griffonia simplicifolia	Leguminosae-Caesalpinioidea	leaves, root	Dysentery, abortion, Fracture, pelvic congestion
Ocimum gratissimum	Lamiaceae	leaves	Dysentery, malaria, sinusitis, allergic, fever, rhinitis, constipation
Carapa procera	Meliaceae	bark	Asthma, cough
Dialum guineense	Leguminosae-Caesalpinioidea	bark, root	Piles
Piliostigma thonningia	Leguminosae-	leaves	Uterine hemorrhage

	Caesalpinioidea		
Afzelia Africana	Leguminosae-Caesalpinioidea	bark, leaves	Rheumatic joint disease
Maytenus senegalensis	Celestraceae	leaves, root	Convulsion, piles
Bridelia ferruginea	Phyllanthaceae	leaves, bark,	Rheumatic pain, oedema, mouth wash, dysentery, diarrhoea,intestinal problem
Parquitina nigrescence	Periplocaceae	leaves,root, stem	Snake-bite
Canthium glabrifolium	Lamiaceae	stem, leaves	Palpitation of heart, placenta retention
Khaya senegalensis	Meliaceae	bark	Convulsion, arthritis, boils, hemorrhoids
Heliotropium indicum	Boragninaceae	root	Piles, folliculitis
Kigelia Africana	Bignoniaceae	bark, leaves	Arthritis, ear-ache, otitis media
Eastern Region			
Morinda lucida	Rubiaceae	bark, leaves, root	Dysentery, malaria, amenorrhoea
Cryptolepis sanguinolenta	Pereplocaceae	root, leaves	Antimalaria, antipyretic
Adenia cissampeloides	Passiflorceae	stem, leaves,	Anaemia, ulcers bronchitis, dysentry, malaria, fever
Monodora myristica	Annonaceae	seed	Anaemia, hemorrhoids, sexual weakness, wound
Paullinia pinnata	Sapindaceae	root	Cellulitis, sexual weakness, cough, dysentery
Mitragya stipulosa	Rubiaceae	bark leaves	Ulcer, chest pain, kidney oedema, rheumatism
Clausena anisata	Rutaceae	leaves, stem	Arthritis, asthma, laxative (children)
Markhamia lutea	Bigononiaceae	bark, leaves	Rheumatism, wound
Olax subscorpiodea	Olacaceae	leaves, stem, root	Hypertension, infective hepatitis
Spathodea campanualata	Bignoniaceae	root, leaves, bark	Dysentery, stomachache, foetus (unable to develop)
Antiaris Africana	Moraceae	bark	Syphilis, sore throat, expulsion of placenta
Desmodium adscendens	Leguminosae-Papilionoideae	leaves	Asthma, diarrhea
Pseudocedrella kotschyi	Meliaceae	bark, leaves	Asthma
Ageratum conyzoides	Asteraceae	leaves	Convulsion, conjunctivitis (eye inflammation)
Diodea scandens	Rubiaceae	leaves	Antimicrobial
Bidens pilosa	Compositae	leaves	Epidermophyton of skin, urticalia (allergy)
Cneitis ferruginea	Connaraceae	leaves, root	Anaemia, cough, Morasmus
Lecaniodiscus cupaniodes	Sapindaceae	bark, leaves	Cough

Lippia multiflora	Verbenaceae	leaves	Epilepsy
Trichilia heudelotti	Meliaceae	root,stem, leaves	Arthritis, insanity cough, abdominal pain dysmenorrhoea, leuchorrhoea
Microglossa pyrifolia	Asteraceae	bark, leaves root,	Fever, hard labour, colds, headache, anthelminthis,
Strophanthus hispidus	Apocynaceae	leaves, root, stem	Rheumatism, arthritis, hypertension, sexual weakness, constipation
Combretum smeathmannii	Combretaceae	leaves	Rheumatism, helmenthiasis, Chest pain,
Cassia podocarpa	Leguminosae-Caesalpinioideae	leaves	Gonorrhoea
Acanthospermum hispidum	Asteraceae	leaves	Jaundice

Collection and Preparation of Soil and Medicinal Plant Samples

Debris at soil sampling sites were weeded and soil samples gathered at a depth of 0 – 15 cm (Feng et al., 2018) using soil auger at locations where medicinal plants were procured. Thirty-eight (38) different soil samples were gathered from the study sites in triplicates. Soil samples were collected at a radius of 5 m from the location of the medicinal plant of interest. Soils were dug and mixed to get a composite sample. Soil samples were placed in clean acid-washed receptacles. Soil samples were air-dried at room temperature for seven days to reduce amount of soil moisture since higher content disturbs the analysis using XRF (Zand et al., 2020).

Purposive sampling was carried out after consultation with herbal practitioners in Kumasi to know medicinal plants they had been employing in their trade and their habitats. Information gathered from herbal practitioners on medicinal plant species were documented. Some communities in the Eastern region were at less distant from each other. For instance, Kwahu-Asakraka, Kwahu-Bepong, Kwahu-Kotoso, Bukuruwa and Kwahu-Tafo were at a minimum distance of 10 km apart. These aforementioned towns were about 30 km and 34 km from Nkawkaw and Kwahu-Ankoma respectively. Adawso was at a farthest distance of 101 km from Nkawkaw. Kumasi the capital of Ashanti region is approximately 56 km from Asante-Mampong, Kumawu, Konongo but 5 km, 12 km, 25 km and 112.8 km from Tafo, Ayeduase, Donaso-Ejisu and Ejura respectively. Location and gathering of medicinal plant samples followed the approach employed by herbal practitioners during their normal collection practices, i.e. searching purposely for the medicinal plants of interest. The initial step in sample gathering was a survey embarked upon in the selected communities escorted by a botanist.This was followed by searching farmlands, secondary forests, sacred groves and home gardens back yard gardens for the medicinal plants. On finding any of the medicinal plants of interest, they were identified, and parts (stems, branches, roots, seeds) claimed to have therapeutic properties were gathered under the supervision of a botanist. The medicinal plants identified were tagged (individual plants were given codes and attached to medicinal plants of interest for easy identification). Specimen vouchers were kept at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAM-

USTED), College of Agriculture Education, Asante – Mampong. Samples were placed in labeled receptacles and transported to the laboratory.

Medicinal plant samples gathered were washed with distilled water to free them from dirt. They were air-dried and further oven dried at a temperature of 40℃ for two days and pulverized using pestle and mortar. Samples were sieved using 25 mm mesh, kept in clean receptacles and kept in a refrigerator. The sieved samples were kept in coded receptacles awaiting analysis.

Determination of hazardous metals content of soils

Samples gathered from sites were air-dried. Samples were crushed using pestle and mortar.They were sieved using 250 µm mesh size using USA Standard Testing Sieve ASTM E 11.Samples were placed in coded receptacles. Levels of metals were determined using a Niton XL3t Gold field portable X-ray fluorescence spectrometer using USEPA Method 6200 (US EPA, 2007).Prior to employing XRF analyzer for soil sample analysis a system check of the equipment was carried out and a NIST 2709a reference material was run. This produced recovery of ≥75±5% always. The reproducibility tests performed generated acceptable average relative percent difference (21% for As, 11% for Cu, 13% for Pb and 7.7% for Cd. Niton XL3 GOLDD+ X-ray fluorescence (XRF) was used to analyze the soils for the presence of hazardous metals (Pb, As, Cu and Cd) excluding mercury, in a portion of sieved soil filled to a three - quarter full of a polyethene container. A triplicate sample analysis was carried out and the average of the readings computed.

Soil Mercury Analysis

Soil mercury determination depended on atomization of mercury in the Lumex PYRO-915+ pyrometer and subsequent determination by atomic absorption spectrometry employed in the RA-915M Zeeman mercury analyzer (Lumex, St. Petersburg, Russia).

Amounts of dried soil samples ranging (0.2 – 0.5g) were weighed using an analytical balance and placed into an injection spoon of the PYRO-915+ attachment. The mercury analyzer was run at an airflow rate of 1 L/min and has a detection limit of 0.0005 mg/kg.

Mercury content in the sample was found from the integrated analytical signal with due account of the pre-set calibration coefficient from the activated charcoal reference material (Cat: 500292 Lumex, Russia).

Digestion and Analysis of Medicinal Plant Samples

Medicinal plant samples were subjected to dry ashing. A known weight of medicinal plants samples were placed in porcelain crucibles and dried at 110°C. The ash was moistened using magnesium nitrate. Ashing commenced in a controlled muffled furnace at 450℃ for 24 hours until organic components were thoroughly oxidized. Ash of each selected sample was dissolved in 20 mL of HNO_3 and perchloric ($HClO_4$) acids mixture in the ratio of 9:4 in a 200 mL digestion tube. It was then heated using a block digester to ensure complete dissolution of ash in acid. Heating continued until brown fumes of nitric acid stopped and solution turned clear. Digestion was stopped and distilled water added to obtain a total volume of 20 mL. Solution was filtered through a 0.45 µm pore size membrane filter paper. Analyte was poured into a beaker and the capillary dipped into it, the analyte was aspirated with the VARIAN SPECTRA AA220 Zeeman Atomic Absorption Spectrometer (AAS) (Varian Canada Inc.). Determinations of the various metals (triplicates) in each sample were then carried out and mean values recorded.

Quality Control

To make sure samples were free from contaminants which would affect the results all glasswares and receptacles were washed with distilled water. They were further cleaned with 10 % nitric acid solution. They were rinsed thoroughly with Milli-Q water, dried and kept in dessicator. All reagents were Merck chemicals, Germany analytical grade.

Bioconcentration Factor (BCF), Bioaccumulation Coefficient (BAC) and Translocation Factor of Hazardous Metals

Phytoremediation is one of the classical ways of evaluating the capability of plants to absorb hazardous metals from the soil. It tends to measure the easiness or difficulty for plant to absorb nutrients and store it within its parts. Bioconcentration factor is estimated on the ability of plants to remove metal compounds from soil whereas the translocation is the ability of the plant to transfer the compound from plant root to other organs of the plant.

In order to evaluate the phytoremediation efficiency of the medicinal plants used for analysis, BCF, BAC (Porter et al., 2010) and TF were considered and evaluated.

Bioconcentration Factor (BCF)
The bioconcentration factor (BCF) is represented as the ratio of plant roots to soil, calculated as follows:
Bioconcentration Factor (BCF)=$[\text{Metals}]_{\text{roots}}$ / $[\text{Metals}]_{\text{soil}}$

(Yoon et al., 2006)

Bioaccumulation Coefficient (BAC)
The bioaccumulation coefficient is expressed as the ratio of plant shoot to that of soil, represented as follows:
Bioaccumulatio Coefficient (BAC)=$[\text{Metals}]_{\text{shoots}}$ / $[\text{Metals}]_{\text{soil}}$

(BAC) (Cui et al., 2007; Li et al., 2007)

Translocation factor (TF)
The translocation factor is determined as a ratio of the heavy metal in plant shoot to that in plant root represented as follows:

Translocation Factor (TF)=$[\text{Metals}]_{\text{shoots}}$ / $[\text{Metals}]_{\text{roots}}$

(Cui et al.,2007; Li et al., 2007)

Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

RESULTS AND DISCUSSION

The Table 2 and Table 3 depicted the variation in levels of hazardous metals in soils and medicinal plants from medicinal plants sampling sites in towns from Ashanti and Eastern Regions. The normal levels of Pb, As, Cu. Cd and Hg in the soils and medicinal plants were : Pb (2-300) µg/g, As (0.1-40) µg/g, Cd (0.01- 2) µg/g (Radojevic and Bashkin,2006), Cu (5-30mg/kg) (Okieimen and Wuana, 2011) and Hg (0.5 - 5 mg/kg) (Kabata-Pendiata, 2011) and Pb (0.20 -20) µg/g, As (0.02-20) µg/g, Cd (0.1-2.4) µg/g, (Radojevic and Bashkin, 2006), Cu (10) µg/g and Hg (<0.005-0.02) µg/g respectively.The calculated mean Pb, As, Cu and Hg levels in the soils fell within normal range except that of Cd.The levels of hazardous metals (Pb, As, Cu, Cd and Hg) fell within that of normal levels for medicinal plants except that Hg.

Table 2 Concentration of Hazardous Metals in Soil Samples (Ashanti and Eastern Regions) in mg/kg

Town	**Ashanti Region**				
	Concentration ± SD (mg/kg)				
	Pb	As	Cu	Cd	Hg
Kumasi	3.66±1.85	6.55±1.03	11.02±2.89	7.11±1.04	0.0164±0.002
	3.19±1.32	2.54±0.23	8.87±1.86	6.03±1.02	0.0463 ± 0.01
	3.50±1.82	4.42±0.95	10.19±2.54	6.35±1.21	0.0537 ± 0.02
Mean	**3.45**	**4.50**	**10.02**	**6.50**	**0.04**
	3.93±1.45	3.37±0.65	8.87±1.78	4.29±0.90	0.0488 ± 0.01
	3.32±1.05	6.57±1.85	11.37±3.24	5.31±0.54	0.1048 ± 0.03
Ejura	2.93±0.53	2.37±0.56	8.87±0.91	5.29±0.49	0.004± 0.001
	6.61±2.21	2.99±0.43	9.04±1.92	6.96±1.23	0.0580 ± 0.01
	3.43±1.23	7.52±1.97	9.90±1.84	6.83±1.01	0.0165±0.003
Mean	**4.04**	**4.56**	**9.61**	**5.74**	**0.05**
Donaso-Ejisu	11.22±2.8	3.57±2.17	23.20±3.62	5.88±0.57	0.0722 ± 0.02
	3.36±1.04	5.85±1.89	15.25±4.17	6.47±0.65	0.0455 ± 0.01
Mean	**7.29**	**4.71**	**19.23**	**6.18**	**0.06**
Asante-Mampong	4.15±2.02	6.72±1.15	13.20±3.65	15.28±3.01	0.0704 ± 0.01
Mean	**4.15**	**6.72**	**13.20**	**15.21**	**0.0704**
Kumawu	3.38±1.24	6.73±0.94	9.29±2.02	5.53±1.30	0.0498±0.001
Mean	**3.38**	**6.73**	**9.29**	**5.53**	**0.0498 0.**
Konongo	4.37±2.51	3.83±0.23	12.54±3.35	5.58±1.10	0.0303 ± 0.01
Mean	**4.37**	**3.83**	**12.54**	**5.58**	**0.0303**
Mean (Ashanti Region)	**4.39**	**4.85**	**11.66**	**6.69**	**0.0474**
	Eastern Region				
Kwahu-Bepong	3.52±0.82	6.47±0.94	15.06±3.35	5.39 ±1.21	0.0832 ± 0.02
	2.52±0.54	5.47±1.03	16.06±3.35	4.39±1.34	0.0617 ± 0.03
	3.76±0.73	5.53±2.03	20.65±3.81	5.52±1.51	0.0243 ± 0.01
	2.01±0.43	2.77±0.65	9.11±1.21	6.34±2.30	0.0823 ± 0.03
Mean	**2.95**	**5.06**	**15.22**	**5.41**	**0.06**

Kwahu-Asakraka	3.68±1.02	5.27±1.00	12.56±3.31	5.60±1.31	0.0512 ± 0.01
	3.43±0.75	5.86±1.01	9.50±2.03	5.64±1.31	0.0427 ± 0.02
	3.02±1.00	3.14±0.65	7.67±2.23	4.23±0.98	0.0354 ± 0.01
	4.06±2.04	7.63±1.12	16.36±4.84	6.91±1.33	0.0643 ± 0.02
	3.84±0.67	6.65±1.05	20.53±4.32	6.86±0.89	0.0068 ±0.002
	4.01±1.02	4.46±1.10	12.82±2.22	10.01±3.11	0.0595 ± 0.02
	3.17±0.75	4.60±0.90	10.04±2.45	4.27±2.01	0.0443 ± 0.01
	3.52±0.68	2.83±0.51	10.81±2.52	10.01±3.67	0.0526 ± 0.02
	3.39±0.79	4.85±0.92	9.14 ±1.12	5.48±2.02	0.0420 ±0.001
	3.37±0.81	4.65±0.76	9.76 ±1.23	6.27±2.01	0.0350 ±0.011
	2.42±0.57	2.73±0.43	10.61±3.02	10.01±1.32	0.1256 ±0.02
Mean	**3.45**	**4.79**	**11.80**	**6.85**	**0.05**
Kwahu-	2.61±0.46	6.14±1.45	8.23±1.02	6.23 ±1.12	0.0442 ± 0.02
Ankoma	2.71±0.64	2.21±1.47	8.50 ±0.92	5.23±1.02	0.0085±0.003
	3.91±0.73	3.08±0.67	10.79±2.04	7.46±2.03	0.0033 ±0.001
Mean	**3.08**	**3.81**	**9.17**	**6.31**	**0.02**
Kwahu-Tafo	3.37±0.66	2.82±0.91	10.59±2.92	7.56±1.01	0.0417 ± 0.03
Mean	**3.37**	**2.82**	**10.59**	**7.56**	**0.0417**
Bukuruwa	3.77±0.67	11.01±1.13	10.01±2.01	5.90±2.01	0.0223 ± 0.01
Mean	**3.77**	**11.01**	**10.01**	**5.90**	**0.0223**
Kwahu-Kotoso	3.44±0.32	5.24±1.00	11.10±3.29	5.51±2.22	0.0493±0.01
	3.50±0.01	14.80±1.54	56 ±11.09	6.04±2.44	0.2967 ± 0.05
Mean	**3.47**	**10.02**	**33.55**	**5.78**	**0.173**
Nkawkaw	4.06±2.49	5.37±1.23	9.10 ±2.32	5.48±1.51	0.0347 ±0.001
	3.34±0.32	3.33±1.01	8.61±1.45	5.02±1.67	0.0858 ± 0.03
Mean	**3.70**	**4.35**	**8.86**	**5.25**	**0.06**
Adawso	3.32±0.67	9.37±1.21	8.32±1.34	5.091±0.47	0.0693 ± 0.02
Mean	**3.32**	**9.37**	**8.32**	**5.091**	**0.0693**
Mean (EasternRegion)	**3.39**	**6.40**	**13.44**	**6.02**	**0.06**

Source : (Sarpong et al., 2022)

Table 3 Concentration of Hazardous Metals in Medicinal Plant Samples from Ashanti and Eastern Regions in mg/kg

Medicinal Plant	Plant Part	Town	Pb	As	Cu	Cd	Hg
Griffonia simplicifolia	leaves	Kumasi	BDL	1.20±0.4501	0.19±0.2101	1.2411±0.0011	0.5434±0.0021
	root		0.0579±0.0008	0.31±0.0110	0.09±0.0002	0.1045±0.0007	0.3211±0.1211
Ocimum gratissimum	leaves		0.2004±0.0002	1.64±0.0120	0.39±0.001	0.0179±0.0011	4.66±1.0121
Carapa procera	bark		0.032±0.00	3.11±0.0	0.17±0.1	0.1295±0.0	0.6531±0.12

			04	031	110	009	11
Dialum guineense	bark	Ejura	0.4826±0.0005	1.15±0.1103	0.31±0.0002	0.1345±0.0017	0.6213±0.1211
	root		0.4032±0.0006	0.52±0.1150	0.18±0.0021	0.1075±0.0007	0.8121±0.0001
Piliostigma thonningia	leaves		0.216±0.0005	1.23±0.1103	0.65±0.1121	0.0243±0.0019	0.6213±0.0003
Afzelia Africana	bark		0.1830±0.0007	0.56±0.1121	0.14±0.0011	0.1676±0.0012	4.8100±0.2111
	leaves		0.2054±0.0003	0.74±0.3001	0.10±0.1001	0.1320±0.0001	2.1121±0.1101
Maytenus senegalensis	root		0.2152±0.0011	1.03±0.1002	0.26±0.1103	0.1345±0.0005	0.2400±0.0211
	leaves		0.1121±0.1001	0.43±0.1113	0.53±0.0121	0.4112±0.1101	0.3500±0.1021
Bridelia ferruginea	leaves		0.3738±0.0003	0.69±0.1112	0.32±0.0103	0.0466±0.0031	20.0900±2.0121
	bark		0.3990±0.0008	0.97±0.1121	0.13±0.0001	BDL	0.2110±0.0041
Parquitina nigrescence	leaves	Asante-Mampong	0.1241±0.0009	1.34±0.1211	0.29±0.0002	0.0195±0.0026	4.0123±0.0003
	root		0.2651±0.0009	0.37±0.2110	0.27±0.1311	0.1498±0.0008	6.6000±1.2123
	stem		0.0105±0.0002	0.29±0.0123	0.29±0.0003	0.0383±0.0003	5.1032±0.2321
Canthium glabrifolium	leaves	Konongo	0.5904±0.0008	0.90±0.0113	0.15±0.0114	0.0498±0.0023	0.1100±0.0002
	stem		0.5557±0.0004	0.28±0.0031	0.07±0.0001	0.0192±0.0005	4.8100±1.0022
Khaya senegalensis	bark	Donaso-Ejisu	0.8297±0.0019	0.78±0.4121	0.07±0.0001	0.0938±0.0002	0.2200±0.0201
Heliotropium indicum	root		0.3213±0.0003	0.93±0.1101	0.12±0.1221	0.0131±0.0035	3.0121±0.4211
Kigelia Africana	bark	Kumawu	0.3990±0.0004	1.43±0.0112	0.25±0.0211	0.1199±0.0005	0.1500±0.0111
	leaves		0.0658±0.0035	0.46±0.0311	0.14±0.0011	0.1530±0.0011	0.1146±0.0002
			EASTERN REGION				
Morinda lucida	bark	Kwahu-Bepong	BDL	1.35±0.0121	0.30±0.0121	0.0836±0.0003	0.5523±0.2111
	leaves		0.1301±0.1110	0.73±0.0032	0.82±0.1121	0.0651±0.0112	0.2321±0.0112

Advanced International Journal for Research (AIJFR)

E-ISSN: 3048-7641 ● Website: www.aijfr.com ● Email: editor@aijfr.com

	root		0.1905±0.001	0.88±0.0011	0.20±0.1112	0.1040±0.0017	0.5432±0.0121
Cryptolepis sanguinolenta	leaves		0.6088±0.0009	0.55±0.2131	0.18±0.1212	0.1116±0.0002	1.6121±0.2112
	root		0.3824±0.0006	1.19±0.1121	0.35±0.1121	0.0246±0.0011	3.900±0.0211
Adenia cissampeloides	stem		0.2810±0.0003	1.72±0.0012	0.08±0.1011	1.0596±0.0115	5.3100±0.0312
	leaves		0.0756±0.0003	1.58±0.2111	0.32±0.1121	0.0562±0.0007	3.9210±0.0004
	root		0.1923±0.007	0.43±0.0005	0.34±0.0031	0.1089±0.0006	0.4031±0.0012
Monodora myristica	seed	Kwahu-Asakraka	0.1744±0.0003	0.73±0.3111	0.14±0.1122	0.0444±0.0022	0.1100±0.0001
Paullinia pinnata	root		0.3824±0.0004	0.73±0.0023	0.11±0.1011	0.0913±0.0005	4.5342±0.1121
Mitragyna stipulosa	bark		0.4826±0.0009	0.84±0.1120	0.11±0.0011	0.1982±0.0011	4.4100±0.1211
	leaves		0.3203±0.0001	0.77±0.1210	0.19±0.1022	0.0480±0.0009	2.2113±0.1113
Clausena anisata	stem		0.1713±0.0008	1.93±0.1211	0.24±0.1172	0.1778±0.0003	3.1232±0.2310
	leaves		BDL	0.68±0.1310	0.14±0.1112	0.1371±0.0011	2.1282±0.2211
Markhamia lutea	bark		0.5488±0.0003	0.55±0.2101	0.61±0.1103	0.0624±0.0013	0.41±0.1213
	leaves		0.0737±0.0010	1.76±0.2111	0.29±0.1110	0.1486±0.0005	0.6711±0.0032
Olax subscorpiodea	leaves		0.2940±0.0008	1.82±0.1213	0.19±0.1131	0.0211±0.0015	5.1100±0.2101
	stem		0.1545±0.0006	0.57±0.2312	0.11±0.2111	0.1015±0.0004	0.2300±0.1121
	root		0.7879±0.0003	0.75±0.2111	0.18±0.1102	0.1422±0.0003	18.1400±2.011
Spathodea campanulata	leaves		0.5315±0.0005	0.34±0.1121	0.15±0.0011	0.1216±0.0004	0.4352±0.0211
	bark		0.1566±0.0004	1.69±0.0021	0.25±0.0311	0.1422±0.0008	1.5001±0.3120
	root		0.0421±0.0001	1.69±0.1121	0.25±0.0112	0.1422±0.0008	0.6211±0.0112
Antiaris Africana	bark		0.5026±0.0006	0.14±0.1021	0.10±0.1211	0.1422±0.009	0.3300±0.1212
Ageratum	leaves		0.5973±0.0	0.50±0.1	0.30±0.2	0.0674±0.0	1.7700±0.00

conyzoides			009	102	111	04	21
Diodea scandence	leaves		0.8911±0.2131	0.91±0.0012	1.02±0.0023	0.2104±0.010	4.7200±1.3210
Bidens pilosa	leaves		0.0451±0.0002	1.24±0.2111	0.32±0.1102	BDL	0.0330±0.1212
Cneitis ferruginea	leaves	Kwahu-Tafo	0.5710±0.0012	0.91±0.0103	0.22±0.1101	0.0937±0.0039	4.2541±0.2112
	root		BDL	0.45±0.1101	0.33±0.0012	0.1065±0.0008	5.2800±0.3111
Lecaniodiscus cupaniodes	bark	Bukuruwa	0.9029±0.0006	1.24±0.1221	0.28±0.3101	0.1269±0.0009	3.0012±0.0121
	leaves		BDL	0.50±0.0.012	0.30±0.2101	0.1524±0.0009	0.2105±0.1121
Lippia multiflora	leaves	Adawso	0.5125±0.0006	0.90±0.2111	0.19±0.0121	0.1575±0.0016	4.1232±0.2311
Trichilia heudelotti	root	Kwahu-Ankoma	0.5026±0.004	0.70±0.0021	0.14±0.0011	0.1702±0.001	20.31±2.1212
	leaves		0.3990±0.0008	0.37±0.0211	0.18±0.2311	0.028±0.0013	0.5412±0.1211
	stem		0.2614±0.0004	1.47±0.2001	0.21±0.1141	0.1530±0.0003	0.0009±0.0001
Microglossa pyrifolia	bark		BDL	0.36±0.0002	0.09±0.0010	0.1089±0.0006	0.1123±0.0001
	leaves		0.2161±0.0011	1.47±0.1022	0.55±0.1211	0.1023±0.0003	0.4100±0.1221
	root		0.0184±0.0005	0.83±0.2110	0.18±0.2211	0.003±0.0006	2.3400±0.0011
Strophanthus hispidus	root		0.4448±0.0003	0.67±0.0031	0.8812±0.02	0.1129±0.0013	2.1133±0.1201
	leaves		0.2353±0.0001	1.58±0.0111	0.11±0.3011	0.0949±0.0011	0.7212±0.2114
Combretum smeathmannii	leaves	Kwahu-Kotoso	0.3607±0.0005	1.72±0.0212	0.64±0.0011	0.1088±0.0022	0.8123±0.0001
Cassia podocarpa	leaves		0.1744±0.0002	0.92±0.1211	0.311±0.001	0.0967±0.0017	0.2500±0.2111
Acanthospermum hispidum	leaves	Nkawkaw	0.2160±0.0005	0.65±0.0002	0.67±0.1102	0.0243±0.008	4.9700±0.0012
Pseudocedrella kotschyi	bark		0.2502±0.0004	0.26±0.1131	0.11±0.0011	0.1575±0.009	0.5232±0.0003
	leaves		0.5349±0.0008	0.26±0.1121	0.20±0.1112	0.1093±0.008	0.2102±0.0211

Source :(Acheampong et al., 2024)

Phytoremediation Potential benchmarks

The estimation of BCF, BAC and TF help to identify the suitability of plants for phytoremediation. The phytoremediation comprises of the phyto-extraction or phyto-stabilization of the plant use. This is explained by the values of accumulation characteristics and the behaviour of translocation of metals in plants. According to (Fitz & Wenzel, 2002) when BCF, BAC and TF values > 1, it is considered promising phytoextractor, suitable for phytoextraction.When BCF and TF < 1, the plants are not suitable for phytoextraction / phytostabilization. Nevertheless, plants with BCF > 1 and TF < 1 are considered potential phytostabilizers (Mendez & Maier, 2008) suitable for phytostabilization (immobilization).

Translocation Factor (TF)

The medicinal plant samples gathered from different geographical locations exhibited variation in the movement of hazardous metals by way of TF, BCF and BAC and were as displayed in (Table 4 and Table 5), (Table 6 and Table 7) and (Table 8 and Table 9) respectively.

Table 4 Translocation Factor (TF) of Medicinal Plants from Ashanti Region

Medicinal Plant	Town	Plant Part	Translocation factor				
			Pb	As	Cu	Cd	Hg
Griffonia simplicifolia	Kumasi	leaves	BDL	3.87	2.11	11.88	1.69
Parquitina nigrescence	Asante-Mampong	leaves	0.47	3.62	1.07	0.13	0.61
Parquitina nigrescence		stem	0.04	0.78	1.07	0.26	0.77
Dialum guineense	Ejura	bark	1.20	2.21	1.72	1.25	0.77
Maytenus senegalensis		leaves	0.52	0.42	2.04	3.06	1.46

The results for $TF_{(Ashanti)}$ were as presented in Table 4. The results indicated that, the medicinal plants gathered from Ashanti region were good phytoextractors and could be used for phytoextraction as their performance for extraction of hazardous metals were mostly found to be greater than 1. Majority (56%) of the medicinal plants recorded values above 1 for almost all of the hazardous metals.

The range of $TF_{(Ashanti,Pb)}$ was BDL - 1.20 in *Griffonia simplicifolia* (leaves) from Tafo-Kumasi and *Dialum guineense* (bark) from Ejura respectively. With exception of *Dialum guineense* (bark) from Ejura all the plants had $TF_{(Ashanti,Pb)} < 1$ (Table 4). The $TF_{(Ashanti,Pb)}$ is a measure of amount of metal (Pb) transferred from root to shoot. Medicinal plant having high $TF_{(Ashanti,Pb)}$ indicated high amounts transferred and vice versa. *Dialum guineense* (bark) from Ejura ($TF_{(Ashanti,Pb)} = 1.20$) could be said to be phytoextractors for lead. Also *Dialum guineense* (bark) from Ejura with high concentration of Pb may adversely affect the health of consumers when compared to the rest of the plant parts which had $TF_{(Ashanti,Pb)} < 1$.

$TF_{(Ashanti,Pb)}$ for the medicinal plants were in the order: *Griffonia simplicifolia* (leaves) (BDL) < *Parquitina nigrescence* (stem) (0.04) < *Parquitina nigrescence* (leaves) (0.47) < *Maytenus senegalensis* (stem)(0.52) < *Dialum guineense* (bark)(1.20).

The range of $TF_{(Ashanti,As)}$ was 0.78 - 3.87. The highest $TF_{(Ashanti,As)}$ was in *Griffonia simplicifolia* (leaves) from Tafo-Kumasi with the lowest in *Maytenus senegalensis* (leaves) from Ejura. Apart from *Parquitina nigrescence* (leaves) from Asante-Mampong all the medicinal plants possess $TF_{(Ashanti,As)} > 1$. *Griffonia simplicifolia* (leaves) from Tafo-Kumasi, ($TF_{(Ashanti,As)}$= 3.87), *Parquitina nigrescence* (leaves) from Asante-Mampong ($TF_{(Ashanti,As)}$= 3.62), *Dialum guineense* (bark) and Ejura ($TF_{(Ashanti,As)}$ = 2.21) exhibited phytoextraction properties for arsenic. The order of harm the medicinal plants could cause consumers as a result of the presence of As would be *Griffonia simplicifolia* (leaves) from Tafo-Kumasi > *Parquitina nigrescence* (leaves) from Asante-Mampong > *Dialum guineense* (bark) from Ejura.

$TF_{(Ashanti,As)}$ for the medicinal plants were as shown:*Griffonia simplicifolia* (leaves)(3.87) > *Parquitina nigrescence* (leaves)(3.62) > *Dialum guineense* (bark)(2.21) > *Parquitina nigrescence* (stem) (0.78) > *Maytenus senegalensis* (leaves)(0.42).

Copper exhibited a $TF_{(Ashanti,Cu)}$ range of 1.07 – 2.11 in the medicinal plants. The maximum Cu was found in *Griffonia simplicifolia* (leaves) from Tafo-Kumasi while the minimum was in *Parquitina nigrescence* (leaves) from Asante-Mampong from *Parquitina nigrescence* (leaves) from Asante-Mampong and *Dialum guineense* (bark) from Ejura. Five medicinal plants had $TF_{(Ashanti,Cu)} > 1$. These plants were *Griffonia simplicifolia* (leaves) from Tafo-Kumasi ($TF_{(Ashanti,Cu)}$ = 2.11), *Parquitina nigrescence* (leaves) from Asante-Mampong ($TF_{(Ashanti,Cu)}$ = 1.07), *Parquitina nigrescence* (stem) from Asante-Mampong ($TF_{(Ashanti,Cu)}$= 1.07), *Dialum guineense* (stem) from Ejura ($TF_{(Ashanti,Cu)}$ = 1.72) and *Maytenus senegalensis* (leaves) from Ejura ($TF_{(Ashanti,Cu)}$ = 2.04). These were phytoextractors for copper. Medicinal plants with low Cu content would be preferred as raw materials in the preparation of herbal products since they would be less toxic.

$TF_{(Ashanti,Cu)}$ observed was in the order: *Griffonia simplicifolia* (leaves)(2.11) > *Maytenus senegalensis* (leaves)(2.04) > *Dialum guineense* (bark)(2.07) > *Parquitina nigrescence* (stem)(1.07) , *Parquitina nigrescence* (leaves)(1.07).

Range of $TF_{(Ashanti,Cd)}$ in medicinal plants was 0.13 – 11.88. *Parquitina nigrescence* (leaves) from Asante-Mampong and *Griffonia simplicifolia* (leaves) from Tafo-Kumasi showed lowest and maximum Cd levels respectively. Three medicinal plants namely *Griffonia simplicifolia* (leaves) from Tafo-Kumasi ($TF_{(Ashanti,Cd)}$ = 11.88), *Dialum guineense* (bark) from Ejura ($TF_{(Ashanti,Cd)}$= 1.25) and *Maytenus senegalensis* leaves from Ejura ($TF_{(Ashanti,Cd)}$ = 3.06) showed $TF_{(Ashanti,Cd)} > 1$. These plants were phytoextractors for Cd.The rest [*Parquitina nigrescence* (leaves) from Asante-Mampong ($TF_{(Ashanti,Cd)}$ = 0.13) and *Parquitina nigrescence* (stem) from Asante-Mampong, ($TF_{(Ashanti,Cd)}$=0.26) demonstrated $TF_{(Ashanti,Cd)} < 1$. Due to low toxicity that might arise from low Cd levels *Parquitina nigrescence* (stem and leaves) from Asante-Mampong, would be preferred.

Calculated $TF_{(Ashanti,Cd)}$ demonstrated the order: *Parquitina nigrescence* (leaves)(0.13) < *Parquitina nigrescence* (stem)(0.26) < *Dialum guineense* (bark)(1.25) < *Maytenus senegalensis* (leaves)(3.06) < *Griffonia simplicifolia* (leaves)(11.88).

The range of $TF_{(Ashanti,Hg)}$ levels was 0.61 – 1.69. *Parquitina nigrescence* (leaves) from Asante-Mampong and *Griffonia simplicifolia* (leaves) from Tafo-Kumasi exhibited lowest and highest $TF_{(Ashanti,Hg)}$ levels respectively. Two medicinal plants had $TF_{(Ashanti,Hg)} > 1$ and were *Griffonia simplicifolia* (leaves) from Tafo-Kumasi ($TF_{(Ashanti,Hg)}$=1.69) and *Maytenus senegalensis* (leaves) from Ejura ($TF_{(Ashanti,Hg)}$=1.46). The aforementioned medicinal plants were good phytoextractors for mercury. They would not be preferred in relation to those with $TF_{(Ashanti,Hg)} < 1$ in the preparation of herbal products.
$TF_{(Ashanti,Hg)}$ of the medicinal plants were: *Parquitina nigrescence* (leaves)(0.61) < *Parquitina nigrescence* (stem)(0.77) < *Dialum guineense* (bark)(0.77) < *Maytenus senegalensis* (leaves)(1.46) < *Griffonia simplicifolia* (leaves)(1.69). The Figure 2 is a plot of TF against selected plants from Ashanti Region.

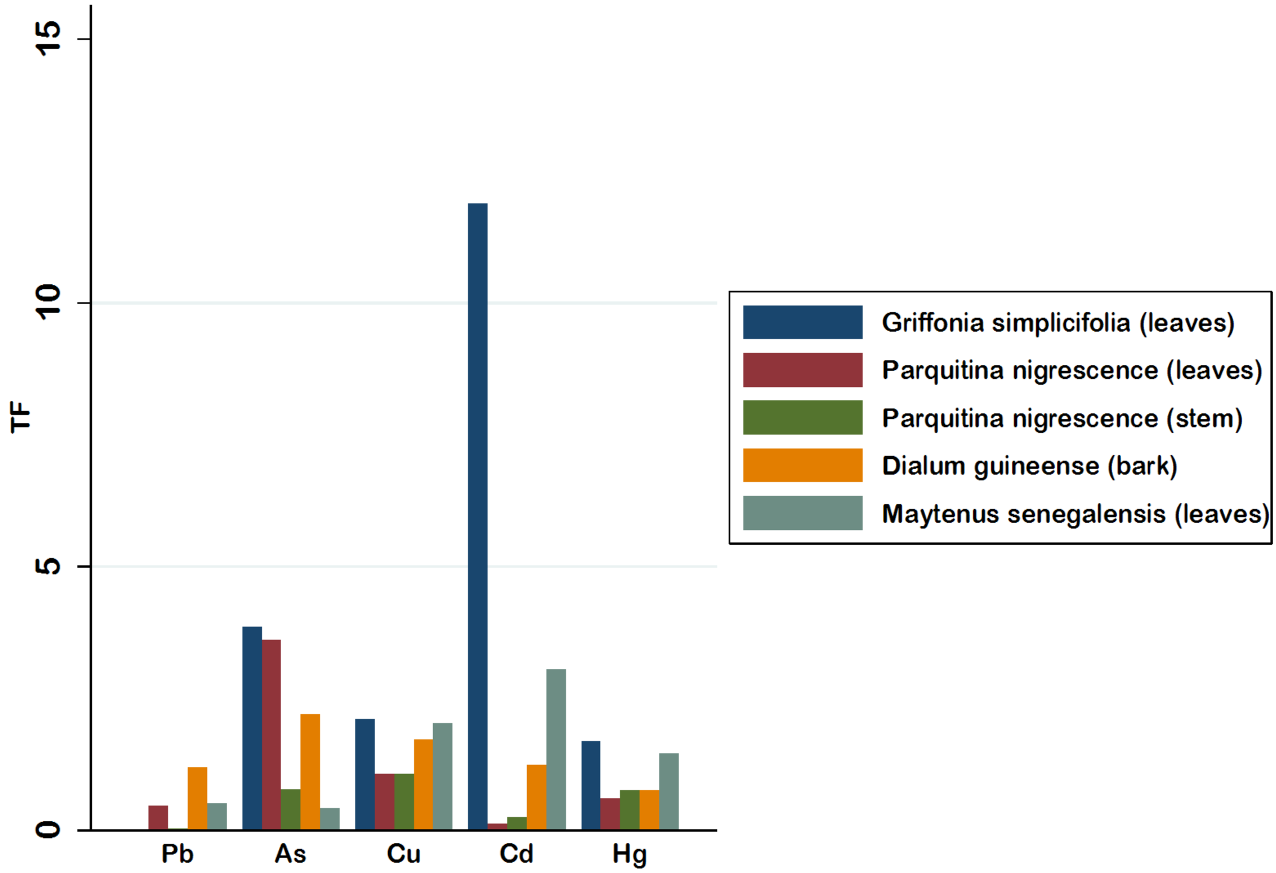

Figure 2: Translocation Factor (TF) - Ashanti Region

Table 5 Translocation Factor (TF) of Medicinal Plants from Eastern Region

Medicinal Plant	Town	Plant Part	Transloction Factor				
			Pb	As	Cu	Cd	Hg
Morinda lucida	Kwahu-Bepong	bark	BDL	1.53	1.50	0.80	1.02
		leaves	0.68	0.83	4.10	0.63	0.43
Cryptolepis sanguinolenta		leaves	1.59	0.46	0.51	4.54	0.41
Adenia cissampeloides		stem	1.46	4.00	0.24	9.73	13.17
		leaves	0.39	3.67	0.94	0.52	9.73
Strophanthus hispidus	Kwahu-Ankoma	leaves	0.53	2.36	0.12	0.84	0.34
Microglossa pyrifolia		bark	BDL	0.43	0.50	36.30	0.05
		leaves	11.74	1.77	3.06	34.10	0.18
Trichilia heudelotti		leaves	0.79	0.53	1.29	0.16	0.03
		stem	0.52	2.10	1.50	0.90	BDL
Cneitis ferruginea	Kwahu-Tafo	leaves	BDL	2.02	0.67	0.88	0.81
Olax subscorpiodea	Kwahu-Asakraka	leaves	0.37	2.43	1.06	0.15	0.28
		stem	0.20	0.76	0.61	0.71	0.01
Spathodea campanulata		leaves	12.62	0.20	0.60	0.86	0.70
		bark	3.72	1.00	1.00	1.00	2.42

On the part of Eastern region, arsenic, copper, and mercury were the only hazardous metals whose extraction recorded phytoextraction properties with majority of the medicinal plants (Table 5). This showed that, there was much phytoextractor in Ashanti region in comparison to Eastern region. This indicated that medicinal plants collected from Ashanti region posed much more risk to humans who ingested them.

The $TF_{(Eastern,Pb)}$ for the medicinal plants fell within the range BDL – 12.62. *Morinda lucida* (bark) from Kwahu-Bepong, *Microglossa pyrifolia* (bark) from Kwahu- Ankoma, *Cneitis ferruginea* (leaves) from Kwahu-Tafo and *Spathodea campanulata* (leaves), Kwahu-Asakraka recorded the lowest and highest $TF_{(Eastern,Pb)}$ respectively.The $TF_{(Eastern,Pb)}$ in these medicinal were above 1: *Cryptolepis sanguinolenta* (leaves) from Kwahu-Bepong ($TF_{(Eastern,Pb)}$ = 1.59), *Adenia cissampeloides*, Kwahu-Bepong ($TF_{(Eastern,Pb)}$ = 1.46), *Microglossa pyrifolia* (leaves) from Ankoma ($TF_{(Eastern,Pb)}$ = 11.74), *Spathodea campanulata* from Kwahu-Asakraka ($TF_{(Eastern,Pb)}$= 12.46) and *Spathodea campanulata* from Kwahu-Asakraka ($TF_{(Eastern,Pb)}$ = 3.72). The aforementioned (i.e. $TF_{(Eastern,Pb)} > 1$) and the result $TF_{(Eastern,Pb)} >1$ in *Dialum guineense* (bark) from Ejura was similar to TF values obtained in a study performed by (Nazir et al., 2011) in plants (*A. pungens, C. sativa, C. pennisetiformis, E. conyzanthus, I. hyderaceae and P. oleraceae* and *P. barbratum*) with TF > 1 from Pakistan.

The $TF_{(Eastern,Pb)}$ in the remaining medicinal plant samples were less than 1 ($TF_{(Eastern,Pb)} < 1$) (Table 5).$TF_{(Eastern,Pb)}$ manifested these order:

Morinda lucida (bark)(BDL), *Cneitis ferruginea* (leaves)(BDL), *Microglossa pyrifolia* (bark) < *Olax subscorpiodea* (stem)(0.20) < *Olax subscorpiodea* (leaves)(0.37) < *Adenia cissampeloides* (leaves)(0.39) < *Trichilia heudelotti* (stem)(0.52) < (*Strophanthus hispidus* (leaves)(0.53) < *Morinda lucida* (leaves)(0.68) < *Trichilia heudelotti* (0.79) < *Adenia cissampeloides* (stem)(1.46) < *Cryptolepis sanguinolenta* (leaves)(1.59) < *Spathodea campanulata* (bark)(3.72) < *Microglossa pyrifolia* (leaves) (11.74) < *Spathodea campanulata* (leaves)(12.62).

The Table 5 showed $TF_{(Eastern,As)}$ range between 0.20 and 4. *Spathodea campanualata* (leaves) from Kwahu-Asakraka recorded the lowest $TF_{(Eastern,As)}$ while *Adenia cissampeloides* (stem) from Kwahu-Bepong recorded the highest. *Morinda lucida* (leaves) from Kwahu-Asakraka ($TF_{(Eastern,As)}$= 0.83), *Cryptolepis sanguinolenta* (leaves) from Kwahu-Bepong ($TF_{(Eastern,As)}$= 0.46), *Olax subscorpiodea (*stem) from Kwahu-Asakraka ($TF_{(Eastern,As)}$ = 0.76) and *Trichilia heudelotti* from Kwahu-Ankoma ($TF_{(Eastern,As)}$= 0.53) and *Spathodea campanulata* (leaves) from Kwahu-Asakraka ($TF_{(Eastern,As)}$ = 0.20) all had $TF_{(Eastern,As)}$ less than 1 ($TF_{(Eastern,As)}$ < 1). The $TF_{(Eastern,As)}$ for the rest of the medicinal plants were greater than 1 ($TF_{(Eastern,As)}$ > 1) (Table 5).

($TF_{(Eastern,As)}$) for medicinal plants were: *Spathodea campanulata* (leaves)(0.20) < *Microglossa pyrifolia* (bark)(0.43) < *Cryptolepis sanguinolenta* (leaves)(0.46) < *Trichilia heudelotti* (leaves)(0.53) < *Olax subscorpiodea* (stem)(0.76) < *Morinda lucida* (0.83) < *Morinda lucida* (bark)(1.53) < *Microglossa pyrifolia* (leave)(1.77) < *Spathodea campanulata* (bark)(1.00) < *Cneitis ferruginea* (leaves)(2.02) < *Trichilia heudelotti* (leaves)(2.10) < *Strophanthus hispidus* (2.36) < *Olax subscorpiodea* (leaves)(2.43) < *Adenia cissampeloides* (leaves)(3.67) < *Adenia cissampeloides* (stem)(4.00).

Translocation factor for copper in the medicinal plants was in the range 0.12 – 4.10. *Stropthanthus hispidus* (leaves) from Kwahu- Ankoma had the lowest $TF_{(Eastern,Cu)}$ with *Morinda lucida* (leaves) from Kwahu-Bepong recording the highest. *Morinda lucida* (bark) from Kwahu-Bepong ($TF_{(Eastern,Cu)}$= 1.50), *Morinda lucida* leaves from Kwahu-Bepong ($TF_{(Eastern,Cu)}$ = 4.10), *Olax subscorpiodea* (leaves) from Kwahu-Bepong ($TF_{(Eastern,Cu)}$=1.06), *Trichilia heudelotti* (leaves) from Kwahu-Bepong ($TF_{(Eastern,Cu)}$=1.29) and *Trichilia heudelotti* (stem) from Kwahu-Bepong ($TF_{(Eastern,Cu)}$ 1.50) were all greater than 1 ($TF_{(Eastern,Cu)}$ > 1) whereas the rest of the medicinal plants possessed $TF_{(Eastern,Cu)}$ less than 1 ($TF_{(Eastern,Cu)}$< 1) (Table 5). *Spathodea campanualata* had $TF_{(Eastern,Cu)}$ =1. The results (i.e $TF_{(Eastern,Cu)}$ >1) for Eastern Region plants mentioned and comparable results obtained from Ashanti Region (Table 4) were similar to findings of TF for Cu in a study conducted by (Nazair et al.,2011) in Pakistan.

$TF_{(Eastern,Cu)}$ for the medicinal plants were: *Strophanthus hispidus* (0.12 < *Adenia cissampeloides* (leaves)(0.24) < *Microglossa pyrifolia* (bark)(0.50) < *Spathodea campanulata*(leaves)(0,60) < *Olax subscorpiodea* (stem)(0.61) < *Cneitis ferruginea* (leaves)(0.67) < *Adenia cissampeloides* (leaves)(0.94) < *Spathodea campanulata* (bark)(1.00) < *Olax subscorpiodea* (leaves)(1.06) < *Trichilia heudelotti* (leaves)(1.29) < *Trichilia heudelotti* (stem)(1.50), *Morinda lucida* (bark)(1.50) < *Microglossa pyrifolia* (leaves)(3.06) < *Morinda lucida* (4.10).

The $TF_{(Eastern,Cd)}$ in medicinal plants was 0.15 – 36.30. Four of the medicinal plants had $TF_{(Eastern,Cd)} > 1$. These were *Cryptolepis sanguinolenta* (leaves) from Kwahu-Bepong ($TF_{(Eastern,Cd)}$ =4.54), *Adenia cissampeloides* (stem) from Kwahu-Bepong ($TF_{(Eastern,Cd)}$ = 9.73), *Microglossa pyrifolia* (bark) from Kwahu-Asakraka ($TF_{(Eastern,Cd)}$ = 36.30) and *Microglossa pyrifolia* (leaves) from Kwahu-Asakraka ($TF_{(Eastern,Cd)}$ = 34.10). The plants with $TF_{(Eastern,Cd)} > 1$ were phytoextractive for cadmium. The rest had $TF_{(Eastern,Cd)}$ less than 1 ($TF_{(Eastern,Cd)} < 1$) could be employed in manufacturing of herbal products whereas the reverse holds. *Spathodea campanualata* had $TF_{(Eastern,Cd)}$ =1.

The $TF_{(Eastern,Cd)}$ in medicinal plants were as shown: *Olax subscorpiodea* (leaves)(0.15) < *Trichilia heudelotti* (leaves)(0.16) < *Olax subscorpiodea* (leaves)(0.15) < *Adenia cissampeloides* (leaves)(0.52) < *Morinda lucida* (leaves)(0.63) < *Olax subscorpiodea* (leaves)(0.71) < *Morinda lucida* (bark)(0.80) < *Spathodea campanulata* (leaves)(0.86) < *Cneitis ferruginea* (leaves)(0.88) < *Trichilia heudelotti*(stem)(0.90) < *Spathodea campanulata* (bark)(1.00) < *Cryptolepis sanguinolenta* (leaves)(4.54) < *Adenia cissampeloides* (stem)(9.73) < *Microglossa pyrifolia* (leaves)(34.10) < *Microglossa pyrifolia* (36.30).

$TF_{(Eastern,Hg)}$ in the medicinal plants fell within BDL – 13.17 in *Trichilia heudelotti* (stem) from Kwahu-Ankoma and *Adenia sissempelodes* (stem) from Kwahu-Bepong respectively. *Morinda lucida* (bark) from Kwahu Bepong had $TF_{(Eastern,Hg)}$=1.02, *Spathodea campanualata* (bark) from Kwahu-Asakraka ($TF_{(Eastern,Hg)}$=2.42), *Adenia cissempelodes* (stem) from Kwahu-Bepong ($TF_{(Eastern,Hg)}$=13.17) and *Adenia cissampelodes* (leaves) from Kwahu-Bepong ($TF_{(Eastern,Hg)}$=9.73) were greater than one ($TF_{(Eastern,Hg)} > 1$). Plants with $TF_{(Eastern,Hg)} > 1$ were phytoextractor for Hg. Most of the medicinal plants (73%) had $TF_{(Eastern,Hg)}$ less than one ($TF_{(Eastern,Hg)} < 1$) (Table 2.2). They might serve as candidates for manufacturing of herbal products.
The $TF_{(Ashanti,As)}$ of (0.42-3.87) and $TF_{(Eastern,As)}$ of (0.20-4) were lower than $TF_{(As)}$ (0.02-19.60) in a study carried out in medicinal plants from Suame Magazine in Kumasi (Sarpong and Dartey,2017). $TF_{(Ashanti,Pb)}$ of (BDL-1.20) was below that of TF_{Pb} = (0.15-8.72) (Sarpong and Dartey,2017) which in turn was below $TF_{(Eastern,Pb)}$ of (BDL-12.62) in the current work. The present study revealed $TF_{(Eastern,Cd)}$ =(0.15-36.30) and $TF_{(Ashanti,Cd)}$=(0.13-11.88) which were all higher than TF_{Cd}=(0.23-7) in a study conducted by Sarpong and Dartey in 2017.

Calculated $TF_{(Eastern,Hg)}$ were in the order:*Trichilia heudelotti* (stem)(BDL) < *Olax subscorpiodea* (stem)(0.01) < *Trichilia heudelotti* (leaves)(0.03) < *Microglossa pyrifolia* (bark)(0.05) < *Microglossa pyrifolia* (leaves)(0.18) < *Olax subscorpiodea* (leaves)(0.28) < *Strophanthus hispidus* (leaves)(0.34) < *Cryptolepis sanguinolenta* (leaves)(0.41) < *Morinda lucida* (leaves)(0.43) < *Spathodea campanulata* (leaves)(0.70) < *Cneitis ferruginea* (leaves)(0.81) < *Morinda lucida* (bark)(1.02) < *Spathodea campanulata* (bark)(2.42) < *Adenia cissampeloides* (leaves)(9.73) < *Adenia cissampeloides* (stem)(13.17). Figure 3 showed a plot of TF against metals in selected plants from Eastern Region.

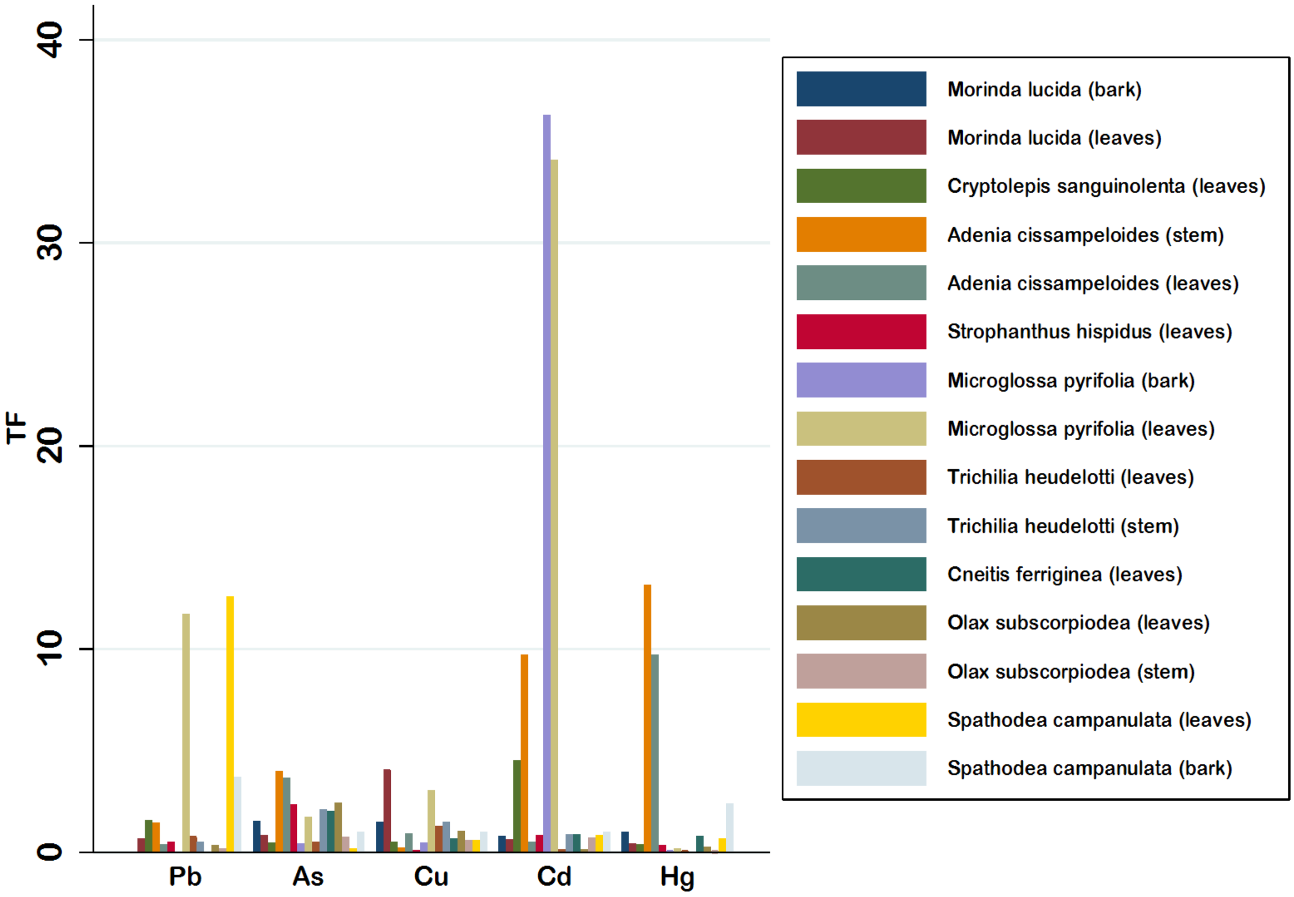

Figure 3: Translocation Factor (TF) - Eastern Region

Bioconcentration Factor (BCF)

The BCF may be considered as the ability of the medicinal plant to accumulate the hazardous metal in its organs. BCF > 1 is a measure of how probable the organism is to bioaccumulate a hazardous metal. BCF of hazardous metals in various plants were as shown in Table 6 and Table 7 for Ashanti regions and Eastern regions respectively. BCF also enables one to ascertain amount of substannce transferred from soil to roots.In our current study the amount of hazardous metal transferred from soil to medicinal plants.Based on this, BCF > 1 were found in mercury for Ashanti region with none of the medicinal plants or the hazardous metals recording more than 50% accumulations. All the plants were possibe phytoextractors for Hg. The ranges of BCF for the hazardous metals were: $BCF_{(Ashanti,Pb)}$ (0.02 – 0.10), $BCF_{(Ashanti,As)}$ (0.06 – 0.43), $BCF_{(Ashanti,Cu)}$ (0.01 – 0.03), $BCF_{(Ashanti,Cd)}$ (0 – 0.03) and $BCF_{(Ashanti,Hg)}$ (5.98 – 93.75).

Table 6 Bioconcentration Factor (BCF) of Medicinal Plants in Ashanti Region

Medicinal Plant	Town	Bioconcentration Factor				
		Pb	As	Cu	Cd	Hg
Griffonia simplicifolia	Kumasi	0.02	0.07	0.01	0.02	5.98

Parquitina nigrescence	Asante-Mampong	0.06	0.06	0.02	0.01	93.75
Dialum guineense	Ejura	0.06	0.17	0.02	0.02	14.00
Maytenus senegalensis		0.07	0.43	0.03	0.03	60.00
Heliotropium indicum	Donaso-Ejisu	0.10	0.16	0.01	BDL	66.20

The levels of $BCF_{(Ashanti,Pb)}$ in the medicinal plants varied. Maximum $BCF_{(Ashanti,Pb)}$ was in *Heliotropium indicum* from Donaso-Ejisu whereas the minimum was in *Griffonia simplicifolia* from Tafo-Kumasi. All the $BCF_{(Ashanti,Pb)}$ for the medicinal plants were less than 1(Table 6). Less level of Pb was accumulated in roots.

$BCF_{(Ashanti,Pb)}$ of the medicinal plants were: *Griffonia simplicifolia* (0.02) < *Maytenus senegalensis*(0.07) < *Parquitina nigrescence* (0.06), *Dialum guineense* (0.06) < *Heliotropium indicum* (0.10).

The highest and lowest $BCF_{(Ashanti,As)}$ was in *Maytenus senegalensis* from Ejura and *Parquitina nigrescence* (stem) from Asante-Mampong. All the medicinal plants had BCF < 1. Less quantities of As was transferred from soil to root (Table 6). Plants could not be phytoextractors for As.

$BCF_{(Ashanti,As)}$ of the medicinal were as shown: *Parquitina nigrescence* (0.06) < *Griffonia simplicifolia* (07) < *Heliotropium indicum* (0.16) < *Dialum guineense* (0.17) < *Maytenus senegalensis* (0.43).

The highest $BCF_{(Ashanti,Cu)}$ was recorded in *Maytenus senegalensis* from Ejura with the lowest $BCF_{(Ashanti,Cu)}$ in *Griffonia simplicifolia* (leaves) from Tafo-Kumasi and *Heliotropium indicum* from Donaso-Ejisu. Plants could not be phytoextractors for Cu.

$BCF_{(Ashanti,Cu)}$ *Griffonia simplicifolia* (0.01), *Heliotropium indicum* (0.01) < *Parquitina nigrescence* (0.02), *Dialum guineense* (0.02) < *Maytenus senegalensis* (0.03).

The highest and lowest BCF of Cd for the medicinal plants were found in *Maytenus senegalensis* from Ejura and *Heliotropium indicum*from Donaso-Ejisu. The BCF of Cd was less than 1. The medicinal plants could not act as phytoextractors for Cd. Less quantities of Cd could be transferred from the soils to the roots. Roots of the medicinal plants would be preferred as raw materials for the preparation of herbal products.

$BCF_{(Ashanti.Cd)}$ *Heliotropium indicum* (BDL) < *Parquitina nigrescence*(0.01) < *Griffonia simplicifolia* (0.02) < *Dialum guineense* (0.02) < *Maytenus senegalensis* (0.03).

The highest $BCF_{(Ashanti,Hg)}$ was in *Parquitina nigrescence* (stem) from Asante-Mampong whereas the lowest was in *Griffonia simplicifolia* from Tafo-Kumasi. The $BCF_{(Ashanti,Hg)}$ for all the medicinal plants were greater than one (BCF_{Hg} >1 implying plants were phytoextractors for Hg. Greater amounts of Hg moved from the soil and accumulated in the root. Raw consumption of the root would adversely affect the health of consumers. The ability to bioaccumulate Hg in the medicinal plants were: *Paullinia pinnata* (106.19) < *Cneitis ferruginea* (126.62) < *Olax subscorpiodea* (344.87) < *Microglossa pyrifolia* (709.09) < *Trichilia heudelotti* (2389.41).

$BCF_{(Ashanti,Hg)}$ *Griffonia simplicifolia* (5.98) < *Dialum guineense* (14.00) < *Maytenus senegalensis* (60.00) < *Heliotropium indicum* (66.20) < *Parquitina nigrescence*(93.75). The figure 4, was a representation of a plot of BCF against selected heavy metals in selected medicinal plants fromAshanti Region.

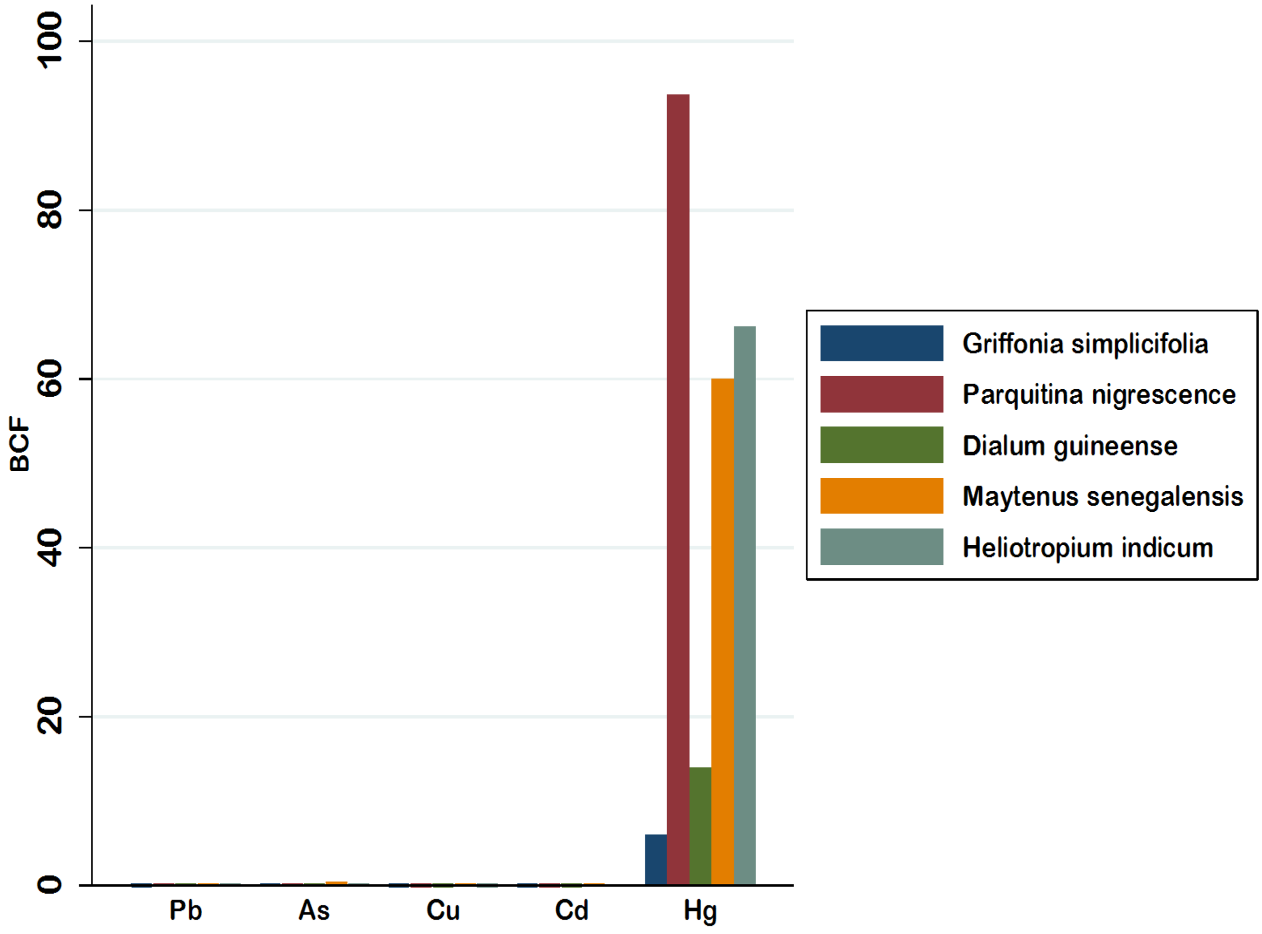

Figure 4: Bioconcentration Factor (BCF) - Ashanti Region

Table 7 Bioconcentration Factor (BCF) of Medicinal Plants from Eastern Region

Name of Medicinal Plant	Town	Bioconcentration Factor (BCF)				
		Pb	As	Cu	Cd	Hg
Morinda lucida	Kwahu-Bepong	0.05	0.14	0.01	0.02	6.53
Cryptolepis sanguinolenta		0.15	0.22	0.02	0.01	63.21
Strophanthus hispidus	Kwahu-Ankoma	0.17	0.11	0.11	0.02	47.81
Trichilia heudelotti		0.19	0.32	0.02	0.03	2389.41
Microglossa pyrifolia		BDL	0.27	0.02	BDL	709.09
Cneitis ferruginea	Kwahu-Tafo	BDL	0.16	0.03	0.01	126.62
Paullinia pinnata	Kwahu-Asakraka	0.11	0.12	0.01	0.02	106.19
Olax subscorpiodea		0.22	0.27	0.02	0.01	344.87

Medicinal plants from Eastern region (Table 7) followed the pattern in Ashanti Region with mercury only recording values greater than 1 indicating a high accumulation. It's worthy to note that plants were phytoextractors for Hg.

The remaining medicinal plants recorded hazardous metals (Pb, As, Cu and Cd) content of less than 1. Mercury recording high levels in the medicinal plants implied consumers' health would adversely be affected thus making the plant parts unattractive to stakeholders. Medicinal plants with lower levels as indicated by BCF contents implied less contamination hence attractive to stakeholders.

$BCF_{(Ashanti,\ Pb)}$ ranged from BDL - 0.22 with the highest BCF_{Pb} occurring in *Olax subscorpiodea* from Kwahu-Asakraka and the least occurring in *Cneitis ferruginea* from Kwahu-Tafo.

$BCF_{(Ashanti,\ Pb)}$ *Microglossa pyrifolia* (BDL), *Cneitis ferruginea* (BDL) < *Morinda lucida* (0,05) < *Paullinia pinnata* (0.11) < *Cryptolepis sanguinolenta* (0.15) < *Strophanthus hispidus* (0.17) < *Trichilia heudelotti* (0.19) < *Olax subscorpiodea* (0.22).

$BCF_{(Ashanti,As)}$ ranged from 0.11 – 0.32, with maximum and minimum BCF_{As} occurring in *Trichilia heudelotti* from Kwahu-Ankoma and *Strophanthus hispidus* from Kwahu-Ankoma respectively.

$BCF_{(Ashanti,As)}$ *Strophanthus hispidus* (0.11) < *Paullinia pinnata* (0.12) < *Morinda lucida* (0.14) < (*Cneitis ferruginea*)(0.16) < *Cryptolepis sanguinolenta* (0.22) < *Olax subscorpiodea* (0.27), *Microglossa pyrifolia* < *Trichilia heudelotti* (0.32) <

The $BCF_{(Ashanti,Cu)}$ ranged from 0.01 – 0.11 with the highest BCF_{Cu} occurring in *Strophanthus hispidus* from Kwahu-Ankoma while the lowest was in *Paullinia pinnata* from Kwahu-Asakraka and *Morinda lucida* from Kwahu-Bepong.

The content of $BCF_{(Ashanti,Cu)}$ for the medicinal plants follwed the order: *Morinda lucida* (0.01), *Paullinia pinnata* (0.01) < *Cryptolepis sanguinolenta* (0.02), *Trichilia heudelotti* (0.02) < *Microglossa pyrifolia* (0.02) < *Olax subscorpiodea* (0.02) < *Cneitis ferruginea* (0.03) < *Strophanthus hispidus* (0.11).

Cadmium had $BCF_{(Ashanti,Cd)}$ ranged from BDL - 0.03 with the maximum occurring in *Trichilia heudelotti* from Kwahu-Bepong and minimum in *Microglossa pyrifolia* from Kwahu-Ankoma. Calculated $BCF_{(Ashanti,Cd)}$ content were:

For $BCF_{(Ashanti,Cd)}$ the order of the medicinal plants were: *Trichilia heudelotti* (BDL) < *Cryptolepis sanguinolenta* (0.01), *Cneitis ferruginea* (0.01), *Olax subscorpiodea* (0.01) < *Morinda lucida* (0.02) < *Strophanthus hispidus* (0.02) <*Paullinia pinnata* (0.02) < *Trichilia heudelotti* (0.03).

The $BCF_{(Ashanti,Hg)}$ ranged from 47.8 - 2389.41 with the highest and lowest occurring in *Trichilia heudelotti* from Kwahu-Ankoma and *Morinda lucida* from Kwahu-Bepong respectively. High BCF_{Hg} implied small amount of Hg remained in the soil while greater amount was transferred to the roots. All plants could serve as phytoextractors for Hg.

The content of $BCF_{(Ashanti,Hg)}$ of the medicinal plants were: *Morinda lucida* (6.53) < *Strophanthus hispidus* (47.81) <*Cryptolepis sanguinolenta* (63.21)<*Paullinia pinnata* (106.19) < *Cneitis* *ferruginea* (126) < *Microglossa pyrifolia* (709.09) < *Olax subscorpiodea* (344.87) < *Trichilia heudelotti* (2389.41).

A high BCF (i.e. above 1000) implied toxic metal had tendency to accumulate harmful metals in plants while moderate BCF (between 100 and 1000) meant harmful metals could accumulate in plants and still harm the environment and as such further investigation is required to ascertain impact on the ecosystem. These medicinal plants: *Paullinia pinnata*, *Olax subscorpioidea*, *Cneitis ferruginea*, and *Microglossa pyrifolia* had $BCF_{(Eastern,Hg)}$ between 100 -1000) and might also have moderate tendency to accumulate in plants and adverse effect on the environment. *Trichilia heudelotti* with $BCF_{(Eastern,Hg)}$ of 2389.41 implied it had a high tendency for bioaccumulation and thus its effects on the ecosystem had to be monitored. Figure 5 depicted a graph of BCF against metals in selected medicinal plants

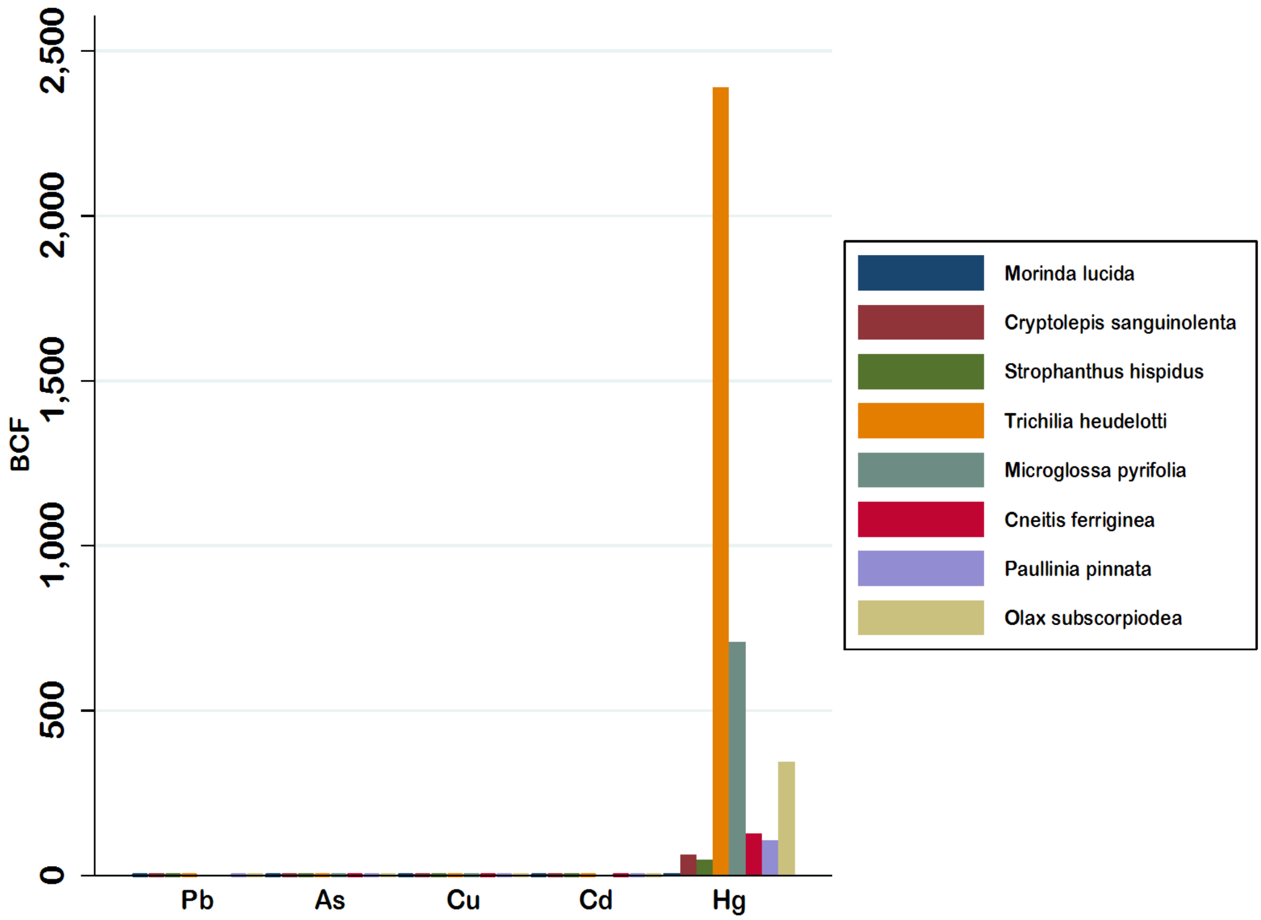

Figure 5: Bioconcentration Factor (BCF) - Eastern Region

Bioaccumulation Coefficient (BAC)

The Table 8 and Table 9 presented the calculated BAC content of the various hazardous metals for the medicinal plants from Ashanti Region and Eastern Regions.

Table 8 Bioaccumulation Coefficient (BAC) of Medicinal Plants from Ashanti Region

Medicinal Plant	Plant Part	Town	Bioaccumulation Coefficient				
			Pb	As	Cu	Cd	Hg
Griffonia simplicifolia	leaves		BDL	0.27	0.02	0.20	10.12
Carapa procera	bark	Kumasi	0.01	0.47	0.02	0.02	39.82
Ocimum gratissimum	leaves		0.06	0.65	0.04	BDL	100.65
Piliostigma thonningia	leaves		0.05	0.36	0.07	0.01	12.73
Afzelia Africana	Bark		0.05	0.07	0.01	0.02	291.52
	Leaves	Ejura	0.06	0.10	0.01	0.02	128.01
Dialum guineense	Bark		0.07	0.38	0.03	0.02	10.71
Maytenus senegalensis	Leaves		0.04	0.18	0.06	0.08	87.50
Bridelia ferruginea	Leaves		0.11	0.11	0.03	0.01	191.70
Bridelia ferruginea	Bark		0.12	0.15	0.01	BDL	2.01
Parquitina nigrescence	leaves	Asante-Mampong	0.03	0.20	0.02	0.00	56.99
Parquitina nigrescence	stem		0.00	0.04	0.02	0.00	72.49
Canthium glabrifolium	leaves	Konongo	0.14	0.23	0.01	0.01	3.63
Canthium glabrifolium	stem		0.13	0.07	0.01	0.00	158.75
Kigelia Africana	bark	Kumawu	0.12	0.21	0.03	0.02	3.01
Kigelia africana	leaves		0.02	0.07	0.02	0.03	2.30
Khaya senegalensis	bark	Donaso-Ejisu	0.07	0.22	BDL	0.02	3.05

It could be observed that the medicinal plants had higher mercury accumulation factors for all the regions with values greater than 1. The range of BAC for the hazardous metals in Ashanti Region were: Pb (BDL – 0.14), As (0.04 - 0.65), Cu (BDL – 0.07), Cd (BDL – 0.08) and Hg (2.01 – 291.52).
Maximum $BAC_{(Ashanti,Pb)}$ was in *Canthium glabrifolium* (leaves) from Konongo whereas *Griffonia simplicifolia* (leaves) from Tafo-Kumasi recordrd BDL.The sequence of $BAC_{(Ashanti,Pb)}$ for the medicinal plants were as shown:

Griffonia simplicifolia (leaves) (BDL) < *Parquitina nigrescence* (stem) (0.00) < *Carapa procera* (bark) (0.01) < *Kigelia africana* (leaves) (0.02) < *Parquitina nigrescence* (leaves) (0.03) < *Maytenus senegalensis* (leaves) (0.04) < *Piliostigma thonningia* (leaves) (0.05), *Afzelia Africana* (bark) (0.05) < *Ocimum gratissimum* (leaves) (0.06), *Afzelia Africana* (bark) (0.06) < *Dialum guineense* (bark) (0.07), *Khaya senegalensis* (bark) (0.07) < *Bridelia ferruginea* (leaves) (0.11) < *Bridelia ferruginea* (bark) (0.12) , *Kigelia Africana* (bark) (0.12) < *Canthium glabrifolium* (leaves) (0.14) (Table 8)

The highest $BAC_{(Ashanti,As)}$ was in *Ocimum gratissimum* from Ayeduase-Kumasi whereas the minimum was in *Parquitina nigrescence* from Asante-Mampong.The observed ranking of $BAC_{(Ashanti,As)}$ for the medicinal plants were as indicated:

Parquitina nigrescence (stem) (0.04) < *Afzelia Africana* (bark) (0.07), *Canthium glabrifolium* (stem) (0.07), *Kigelia africana* (leaves) (0.07) < *Afzelia Africana* (leaves)(0.10) < *Bridelia* *ferruginea* (leaves) (0.11) < *Bridelia ferruginea* (bark)(0.15) < *Maytenus senegalensis* (leaves)(0.18) < *Parquitina nigrescence* (leaves) (0.20) < *Kigelia Africana* (bark) (0.21) < *Khaya senegalensis* (bark) (0.22) < *Canthium glabrifolium* (leaves)(0.23) < *Griffonia simplicifolia* (leaves)(0.27) < *Piliostigma thonningia* (leaves)(0.36) < *Dialum guineense* (bark)(0.38) < *Carapa procera*(bark) (0.47) < *Ocimum gratissimum* (leaves) (0.65) (Table 8).

The highest $BAC_{(Ashanti,Cu)}$ was in *Piliostigma thonningia* (leaves)(0.07) from Ejura whereas *Khaya senegalensis* (bark) recorded BDL.

Khaya senegalensis (bark) (BDL) < *Piliostigma thonningia* (leaves)(0.0 *Afzelia Africana* (leaves)(0.01), *Bridelia ferruginea* (bark)(0.01),*Canthium glabrifolium* (leaves)(0.01), *Canthium glabrifolium* (bark)(0.01) < *Griffonia simplicifolia* (leaves)(0.02), *Carapa procera* (bark) (0.02), *Parquitina nigrescence* (leaves)(0.02), *Parquitina nigrescence* stem)(0.02), *Kigelia africana* (leaves)(0.02) < *Dialum guineense* (bark) (0.03), *Bridelia ferruginea* (leaves)(0.03). *Kigelia Africana* (bark)(0.03) < *Ocimum gratissimum*(leaves) (0.04) < *Maytenus senegalensis* (leaves)(0.06) < *Piliostigma thonningia* (leaves)(0.07) (Table 8).

Maytenus senegalensis recorded the maximum $BAC_{(Ashanti,Cd)}$ while *Bridelia ferruginea* from Ejura and *Ocimum gratissimum* from Kumasi recorded BDL for $BAC_{(Ashanti,Cd)}$.
Ocimum gratissimum (leaves) (BDL), *Bridelia ferruginea* (bark)(BDL) < *Parquitina nigrescence* (leaves)(0.00) < *Canthium glabrifolium* (leaves)(0.00) < *Bridelia ferruginea* (leaves)(0.01) < *Piliostigma thonningia* (leaves) (0.01) < *Canthium glabrifolium* (0.01) < *Griffonia simplicifolia* (leaves)(0.20),*Carapa procera* (bark)(0.20), *Afzelia Africana* (bark) (0.02), *Afzelia Africana* (leaves)(0.02), *Dialum guineense* (leaves)(0.02), *Kigelia Africana* (bark)(0.02), *Khaya snenegalensis* (bark) (0.02) < *Kigelia africana* (leaves)(0.03) < *Maytenus senegalensis* (leaves)(0.08).

Afzelia Africana (bark) and *Bridelia ferruginea* (bark) all from Ejura recorded maximum and minimum $BAC_{(Ashanti,Hg)}$ respectively. The observed trend of $BAC_{(Ashanti,Hg)}$ for the medicinal plants were:
Bridelia ferruginea (bark)(2.01) < *Kigelia africana* (leaves)(2.30) < *Kigelia Africana* (bark)(3.01) < *Khaya senegalensis* (bark)(3.05) < *Canthium glabrifolium* (leaves)(3.63) < *Griffonia simplicifolia* (leaves)(10.12) < *Dialum guineense* (bark) (10.71) < *Piliostigma thonningia* (leaves)(12.73) < *Carapa procera* (leaves)(39.82) < *Parquitina nigrescence* (leaves)(56.99) < *Parquitina nigrescence* (stem)(72.49) < *Maytenus senegalensis* (leaves)(87.53) < *Ocimum gratissimum* (leaves) (100.65) < *Afzelia Africana* (leaves)(128.01) < *Canthium glabrifolium* (leaves)(128.75) < *Bridelia ferruginea* (leaves)(191.70) < *Afzelia Africana* (bark) (291.52) (Table 8).

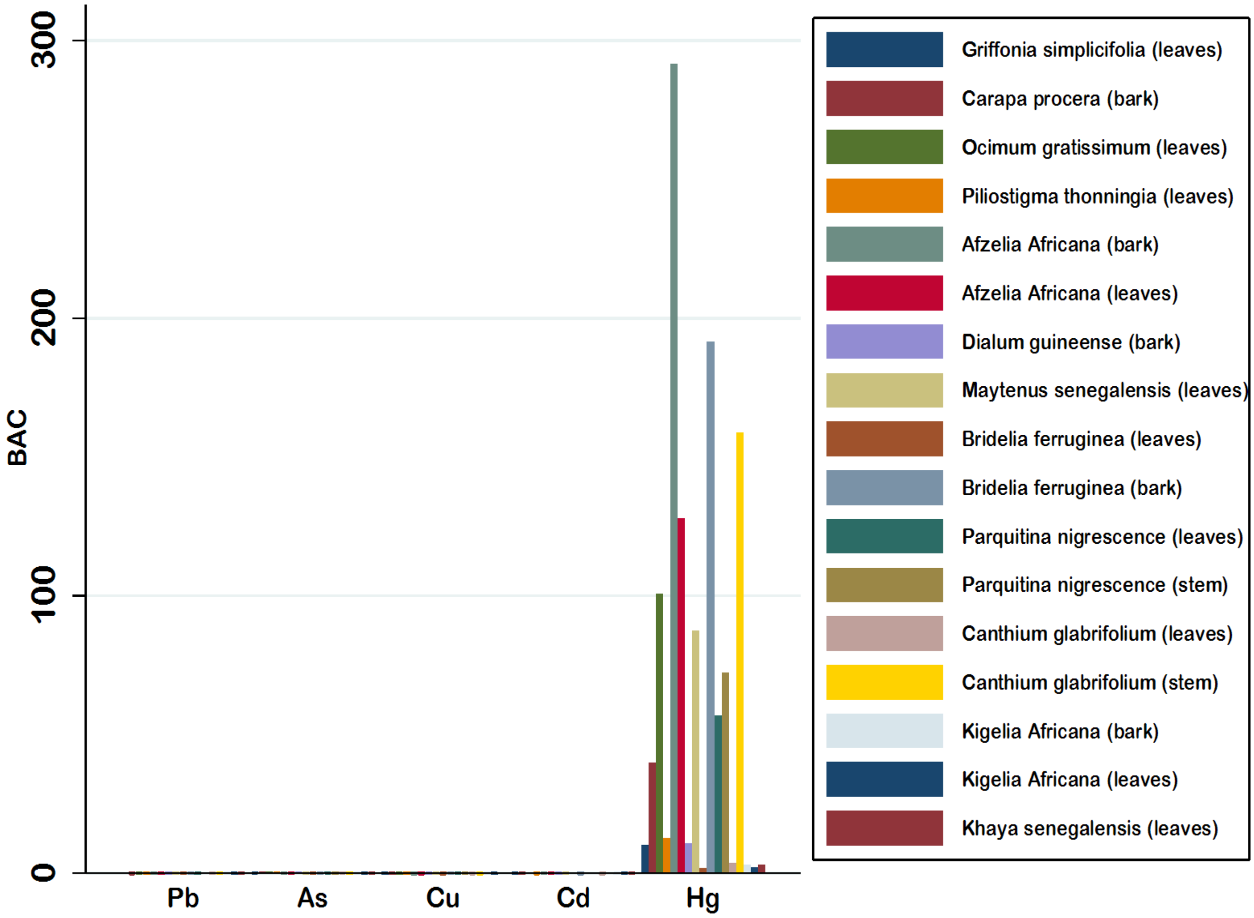

Figure 6: Bioaccumulation Coefficient (BAC) - Ashanti Region

Table 9 Bioaccumulation Coefficient (BAC) of Medicinal Plants from Eastern Region

Name of Medicinal Plant	Town	Plant Part	Bioaccumulation Coefficient				
			Pb	As	Cu	Cd	Hg
Morinda lucida		bark	BDL	0.21	0.02	0.02	6.64
		leaves	0.04	0.11	0.05	0.01	2.79
Cryptolepis sanguinolenta	Kwahu-Bepong	leaves	0.24	0.10	0.01	0.03	26.13
Adenia cissampeloides		stem	0.14	0.62	0.01	0.17	64.52
		leaves	0.04	0.57	0.04	0.01	47.64
Monodora myristica		seed	0.05	0.14	0.01	0.01	2.15
Markhmia lutea		bark	0.18	0.18	0.08	0.01	11.58
		leaves	0.02	BDL	0.04	0.04	18.96
Mitragyna stipulosa	Kwahu-Asakraka	bark	0.20	0.31	0.01	0.02	BDL
		leaves	0.13	0.28	0.02	BDL	BDL
Clausena anisata		stem	0.04	0.25	0.01	0.03	48.57
		leaves	BDL	0.09	0.01	0.02	33.10

Bidens Pilosa		leaves	0.01	0.19	0.02	BDL	4.85
Olax subscorpiodea		stem	0.04	0.20	0.01	0.01	4.37
		leaves	0.08	0.64	0.02	BDL	97.15
Spathodea campanulata		leaves	0.17	0.07	0.01	0.03	9.82
		bark	0.05	0.37	0.02	0.03	33.86
Antiaris Africana		bark	0.13	0.03	0.01	0.01	5.55
Ageratum conyzoides		leaves	0.18	0.10	0.03	0.01	42.14
Diodea scandence		leaves	0.26	0.20	0.10	0.03	134.86
Strophanthus hispidus		leaves	0.09	0.26	0.01	0.02	16.32
Microglossa pyrifolia		bark	BDL	0.12	BDL	0.01	34.03
Microglossa pyrifolia	Kwahu-Ankoma	leaves	0.06	0.48	0.05	0.01	124.24
Trichilia hendelotti		leaves	0.15	0.17	0.02	0.01	63.67
		stem	0.10	0.67	0.02	0.03	0.11
Cneitis ferruginea	Kwahu-Tafo	leaves	0.17	0.32	0.02	0.01	102.02
Lecaniodiscus cupaniodes	Bukuruwa	bark	0.24	0.11	0.03	0.02	134.58
		leaves	BDL	0.05	0.03	0.03	9.44
Lippia multiflora	Adawso	leaves	0.15	0.10	0.02	0.03	59.50
Combretum smeathmannii		leaves	0.10	0.33	0.06	0.02	16.48
Cassia podorcarpa	Kwahu-Kotoso	leaves	0.05	0.06	0.01	0.02	0.84
Acanthospermum hispidum	Nkawkaw	leaves	0.05	0.12	0.07	0.00	143.23
Pseudocedrella kotschyi		bark	0.07	0.08	0.01	0.03	6.10
		leaves	0.08	0.06	1.05	0.04	BDL

The BAC of Pb, As, Cu and Cd for medicinal plants from Eastern Region were lower than 1 except that of Hg which was above 1. This implied the plants had lower accumulation of the hazardous metals in relation to that of Hg which had higher accumulation. The medicinal plants were phytoextractive for Hg. Range of BAC of hazardous metals in medicinal plants were: Pb (BDL – 0.26), As (0.03 - 0.67), Cu (BDL – 1.05), Cd (BDL – 0.17) and Hg (BDL - 143.23).

The maximum BAC_{Pb} occurred in *Diodea scandence* (leaves) from Kwahu-Asakraka whereas *Morinda lucida*, (bark) from Kwahu-Bepong, *Clausena anisata*, (leaves), Kwahu-Asakraka, *Microglossa pyrifolia* from Kwahu-Ankoma and *Lecaniodiscus cupanioides* (leaves) from Bukuruwa had BDL for BAC_{Pb}.

Trichilia heudelotti (stem) from Kwahu-Ankoma showed maximum BAC_{As} whereas the minimum was in *Antiaris africana* (bark) from Kwahu - Asakraka.

The BAC_{Cu} was highest in *Pseudocedrella kotschyi* (leaves) from Nkawkaw and lowest in *Microglossa pyrifolia* () from Kwahu-Ankoma. *Cryptolepis sanguinolenta* (leaves) from Kwahu-Bepong, *Adenia cissampeloides* (stem) from Kwahu-Bepong, *Monodora myristica* (seed) from Kwahu-Asakraka, *Mitragyna stipulosa* (bark) from Kwahu – Asakraka, *Clausena anisata* (stem) from

Kwahu-Asakraka,*Clausena anisata* (leaves) from Kwahu-Asakraka, *Olax subscorpiodea* (stem) from Kwahu-Asakraka, *Spathodea campanulata* (leaves) from Kwahu-Asakraka, *Antiaris africana* (bark) from Kwahu-Asakraka, *Strophanthus hispidus* (leaves) from Kwahu-Ankoma.

and *Cassia podocarpa* (leaves) from Kwahu-Kotoso recorded BAC_{Cu} of 0.01 implying the plants were not phytoextractive for Cu. The rest of the plants with $BAC_{Cu} < 1$ were not phytoextractive for Cu. BAC_{Cd} was maximum in *Adenia cissampeloides* (stem) from Kwahu-Bepong and *Bidens pilosa* (leaves) from Kwahu-Asakraka recorded BDL for Cd. All medicinal plants had $BAC_{Cd} < 1$ meaning they were not phytoextractive for Cd.

BAC_{Hg} in *Mitragyna stipulosa* (leaves) and *Mitragyna stipulosa* (bark) all from Kwahu-Asakraka and *Pseudocedrella kotschyi* (leaves) recorded values BDL while the highest BAC_{Hg} was obtained in *Acanthospermum hispidus* (leaves) from Nkawkaw. Twelve percent (12%) of the plants had $BAC_{Hg} > 1$ implying these plants were phytoextractive for Hg whereas the remaining 78% recorded $BAC_{Hg} <$ 1.These plants were not phytoextractive for Hg.

The $BAC_{(Ashanti,Hg)}$ (2.01-291.52) and $BAC_{(Eastern,Hg)}$ (BDL-143.23) observed in the present study was higher than BAF_{Hg} (0.0005 - 0.0023) (Petelka et al, 2019). In case of BAC_{Cu} , the current values of $BAC_{(Ashanti,Cu)}$ = (BDL- 0.07) and $BAC_{(Eastern,Cu)}$ (BDL-1,05) were below BAF_{Cu} (0.03- 107.88)(Petelka et al,2019).

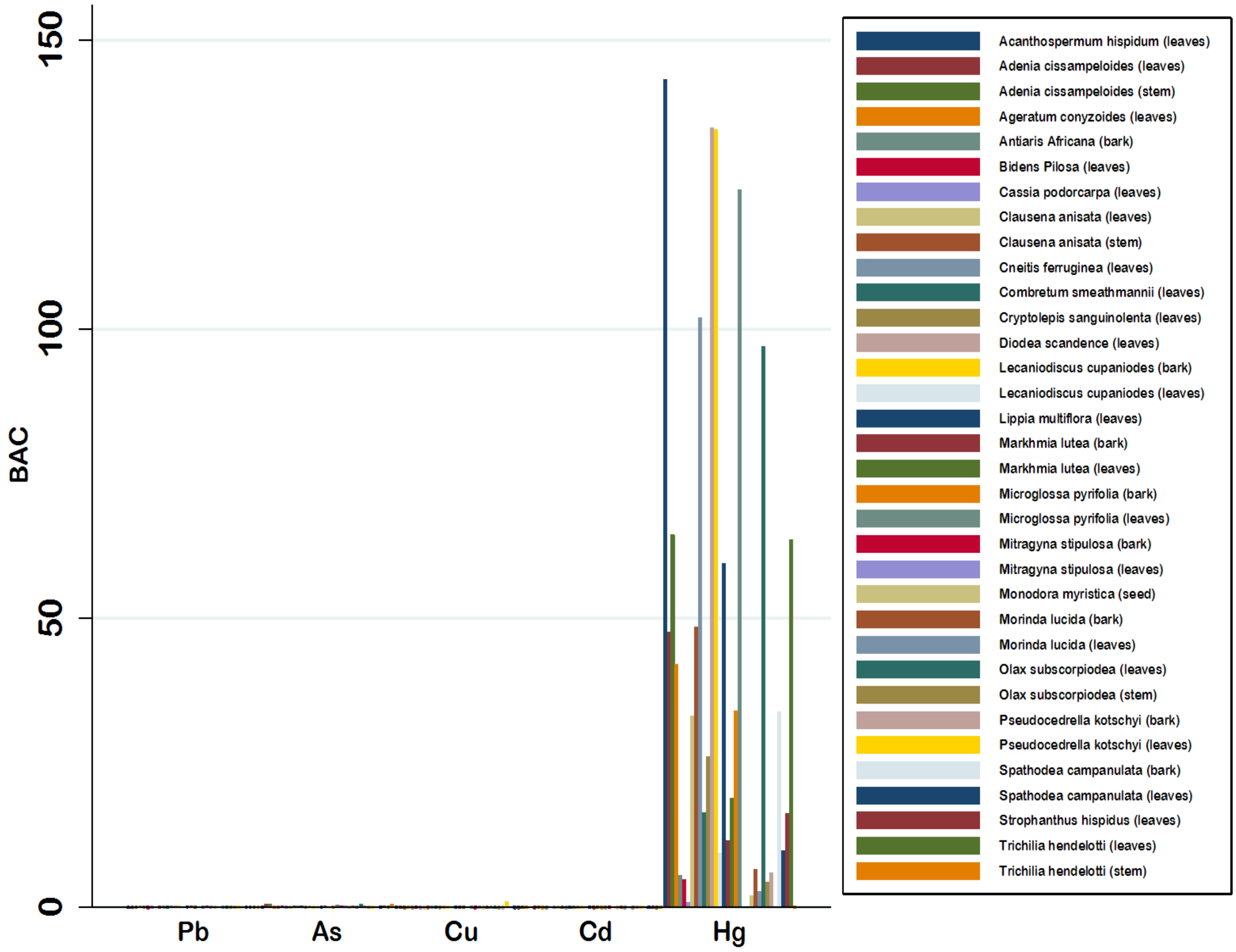

Figure 7: Bioaccumulation Coefficient (BAC) - Eastern Region

Comparing TF, BCF and BAC Contents of Medicinal Plants from Ashanti and Eastern Regions

Translocation Factor

The $TF_{(heavy\ metal)}$ contents of medicinal plants from Ashanti and Eastern Regions varied. TF_{Pb} for the medicinal plants from the two regions fell within BDL - 1.20 and BDL - 12.60 for Ashanti and Eastern regions respectively. The levels were observed in *Griffonia simplicifolia* (leaves) from Kumasi and *Dialum guineense* (bark) from Ejura respectively. The TF_{Pb} for medicinal plants from Eastern region was in the range BDL in *Microglossa pyrifolia* (bark) from Kwahu Ankoma, *Morinda lucida* (bark) from Kwahu - Bepong, *Spathodea campanulata* (stem) from Kwahu-Asakraka respectively. The $TF_{(Pb)}$ for Eastern region plants was higher than that of Ashanti Region. This higher accummulation of Pb make Eastern Region plants better choice as candidates for Pb extraction than those of Ashanti Region.

$TF_{(Cu)}$ for the medicinal plants for Ashanti and Eastern Regions were: $TF_{(Ashanti,Cu)}$; 1.07 in *Parquitina nigrescence* (stem) from Asante-Mampong - 2.11 in *Griffonia simplicifolia* (leaves) from Kumasi. $TF_{(eastern,Cu)}$ showed 0.21 in *Strophanthus hispidus* (leaves) from Kwahu-Ankoma - 4.10 in *Morinda* *lucida* (leaves) from Kwahu Bepong. The maximum $TF_{(Cu)}$ observed in Eastern Region was higher than that of Ashanti Region signifying the selected plants from Eastern Region to be better subjects for Cu uptake.

$TF_{(Ashanti,Cd)}$ exhibited these ranges in the medicinal plants from Ashanti and Eastern Regions.For Ashanti Region: 0.13 in *Parquitina nigrescence* (leaves) from Asante Mampong - 11.88 in *Griffonia simplicifolia* (leaves) from Kumasi. That of Eastern Region was: *Olax subscopodea* (leaves) from Kwahu-Asakraka with a minimum of 0.15 whereas a maximum of 36.30 was recorded in *Microglossa pyrifolia* (bark) from Kwahu-Ankoma. The aforementioned ranges observed in $TF_{(Ashanti,Cd)}$ values from the regions meant medicinal plants from Eastern region had better tendency to remove cadmium from soil better than those from Ashanti region.
$TF_{(Hg)}$ exhibited a range of 0.61 in *Parquitina nigrescence* (leaves) from Asante Mampong to 1.69 in *Griffonia simplicifolia* (leaves) from Kumasi while that of Eastern Region was BDL in *Trichilia heudelotti* (stem) from Kwahu Ankoma to 13.17 in stem of *Adenia cissampeloides* from Kwahu Bepong. The Eastern region plants were phytoextractive for Hg than Ashanti Region.

Bioaccummulation Coefficient

Calculated BAC revealed diverse contents for the Ashanti and Eastern Regions. $BAC_{(Ashanti, Pb)}$ Ashanti Region recorded maximum and minimum contents BDL and 0.14 in *Griffonia simplicifolia* from Kumasi and *Canthium glabrifolium* from Asante Mampong. $BAC_{(Ashanti,Pb)}$ for Eastern Region had BDL in *Morinda lucida* from Kwahu Bepong as minimum with 0.26 in *Diodea scandence* from Kwahu Asakraka as maximum.

$BAC_{(Ashanti,As)}$ for medicinal plants showed these: $BAC_{(Ashanti,As)}$ Ashanti Region; 0.04 in *Parquitina nigrescence* from Asante Mampong - 0.65 in *Ocimum gratissimum.* From Kumasi. $BAC_{(Ashanti,As)}$ Eastern Region; BDL in *Markhmia lutea* (leaves) from Kwahu Asakraka - 0.64 in *Olax subscopodea* (leaves) from Kwahu Asakraka.
$BAC_{(Ashanti,Cu)}$ for the medicinal plants from Ashanti Region recorded a range BDL in *Khaya senegalensis* from Donaso-Ejisu - 0.07 in *Piliostigma thonningia* from Kumasi. For Eastern Region $BAC_{(Ashanti,Cu)}$ was: BDL in *Microglossa pyrifolia* from Kwahu-Ankoma - 0.08 in *Markmia lutea* (bark) from Kwahu-Asakraka.

$BAC_{(Ashanti,Cd)}$ of the medicinal plants for Ashanti Region fell within the range BDL in *Ocimum gratissimum* from Kumasi - 0.20 in *Ocimum gratissimum* also from Kumasi whereas that of Eastern Region was BDL in *Olax subscordea* (leaves), *Bidens pilosa* (leaves) and *Mitragyna stipulosa* (leaves) all from Kwahu-Asakraka - 0.17 in *Adenia cissampeloides* (stem) from Kwahu-Bepong.

$BAC_{(Ashanti,Hg)}$ observed in medicinal plants from Ashanti Region was 2.01 in *Bridelia ferruginea* from Ejura - 291.52 in *Afzelia Africana* from Kumasi while that of Eastern Region was BDL in *Mitragyna stipulosa* (bark), *Pseudocedrella kotschyi* (leaves) from Nkawkaw and *Mitragyna stipulosa* (leaves) - 134.86 in *Diodea scandence* (leaves) from Kwahu Asakraka.

Bioconcentration Factor

Calculation of the BCF contents for metals in the medicinal plants from the regions were different. The observed $BCF_{(Ashanti,Pb)}$ for Ashanti and Eastern Regions were: $BCF_{(Ashanti,Pb)}$ Ashanti Region; *Griffonia simplicifolia* from Kumasi recorded the minimum content of 0.02 whereas the maximum of 0.10 was in *Heliotropium indicum* from Donaso-Ejisu.For Eastern Region $BCF_{(Ashanti,Pb)}$; BDL in *Cneitis ferruginea* from Kwahu-Tafo while the maximum of 0.24 was in *Olax subscorpiodea* from Kwahu-Asakraka.

$BCF_{(Ashanti,As)}$ observed in Ashanti Region had 0.06 in *Parquitina nigrescence* from Asante Mampong with a maximum of 0.43 in *Maytenus senegalensis* from Ejura. $BCF_{(As)}$ Eastern Region recorded a minimum content of 0.11 in *Strophanthus hispidum* from Kwahu-Ankoma whilst *Trichilia heudelotti* from Kwahu-Ankoma had a maximum content of 0.32.

$BCF_{(Ashanti,Cu)}$ Ashanti Region recorded a maximum value of 0.03 in *Maytenus senegalensis* from Ejura with the minimum of 0.01 in *Griffonia simplicifolia* and *Heliotropium indicum* from Kumasi and Ejura respectively. $BCF_{(Cu)}$ Easern Region contained a minimum amount of 0.01 in *Morinda lucida* from Kwahu-Bepong and the maximum was 0.11 in *Strophanthus hispidum* from Kwahu-Ankoma.
$BCF_{(Ashant,Cd)}$ Ashanti Region recorded a minimum content of BDL in *Heliotropium indicum* from Donaso-Ejisu while the maximum was of 0.03 in *Maytenus senegalensis* from Ejura. $BCF_{(Ashanti,Cd)}$ Eastern Region recorded a BDL in *Microglossa pyrifolia* from Kwahu-Ankoma and a maximum value of 0.03 in *Trichilia heudelotti* from Kwahu-Ankoma.

$BCF_{(Ashanti,Hg)}$ Ashanti Region had a minimum amount of 5.98 in *Griffonia simplicifolia* from Kumasi with a maximum of 93.75 in *Parquitina nigrescence* from Asante Mampong. $BCF_{(Ashanti,Hg)}$ Eastern Region had a minimum content of 6.53 in *Morinda lucida* from Kwahu-Bepong and maxmum of 2389.41 in *Trichilia heudelotti* from Kwahu-Ankoma.

These medicinal plants *Morinda lucida*, *Cryptolepis sanguinolenta*, *Strophanthus hispidus*, *Microglossa pyrifolia*, *Trichilia hispidus*, *Cneitis ferruginea*, *Paullinia pinnata*, *Olax subscorpiodea*, *Griffonia simplicifolia*, *Parquitina nigrescence*, *Dialum guineense*, *Maytenus senegalensis* and *Heliotropium indicum* recorded BCF > 1 and TF < 1 and could serve as phytostabilizers.

In all $TF_{(Ashanti, Pb)}$ >1 was 1 [*Dialum guineense* (bark)], $TF_{(Ashanti,As)}$ > 1 were 3[*Griffonia simplicifolia* (leaves), *Parquitina nigrescence* (leaves) and *Dialum guineese* (bark)], all TF_{Cu} > 1 [*Griffonia simplicifolia*, *Parquitina nigrescence*, *Dialum guineense*, *Maytenus senegalensis*, and *Heliotropium indicum*, $TF_{(Ashanti,Cd)}$ > 1 were 3 [*Griffonia simplicifolia* (leaves), *Dialum guineense* (bark) and *Maytenus senegalensi* (leaves) and $TF_{(Ashanti,Hg)}$ > 1 were 2 [*Griffonia simplicifolia* (leaves) and *Maytenus senegalensis* (leaves)].These medicinal plants were phytoextractive for the toxic metal against them and toxic metal were also highly concentrated at the part against them.

$TF_{(Eastern,Pb)}$ had 5 medicinal plants with $TF_{(Eastern,Pb)}$.> 1 and they were: *Cryptolepis sanguinolenta* (leaves), *Adenia cissampeloides* (stem), *Microglossa pyrifolia* (leaves) , *Spathodea campanulata* (leaves) and *Spathodea campanulata* (bark)].These plants were phytoextractive for Pb and greater amounts were found at the part against them.

Eight medicinal plants recorded $TF_{(Eastern,As)} > 1$ and they were: *Morinda lucida* (bark), *Adenia cissampeloides* (stem), *Adenia cissampeloides* (leaves), *Strophanthus hispidus* (leaves), *Microglossa pyrifolia* (leaves), *Trichilia heudelotti* (stem). *Cneitis ferruginea* (leaves) and *Olax subscorpioidea* (leaves). Medicinal plants were phytoextractive for As. High amounts of As was located in the parts stated against plant.

Six medicinal plants recorded $TF_{(Eastern,Cu)} > 1$.The medicinal plants include *Morinda lucida* (bark), *Morinda lucida* (leaves), *Microglossa pyrifolia* (leaves), *Trichilia pyrifolia* (leaves) *Trichilia pyrifolia* (stem) and *Olax subscorpioidea* (leaves). Medicinal plants were phytoextractive for As with greater percentage found at part written against them.

Four medicinal plants registered $TF_{(Eastern,Cd)} > 1$in *Cryptolepis sanguinolenta* (leaves), *Adenia cissampeloides* (stem) *Microglossa pyrifolia* (bark) and *Microglossa pyrifolia* (leaves).

Statistical Analysis

Levels of hazardous metals in soils and medicinal plants were expressed as mean±SD using statistical software SPSS and Microsoft office Excel 2013. The existence of significant difference or not in the TF, BCF and BAC were carried out using STATA-2020 software.

To compare the significance of differences in BAC concentrations between the Ashanti and Eastern Regions (Table 10), two statistical approaches were considered: the Independent Samples t-test, which assumes that the data are normally distributed, and the Mann–Whitney U test, a non-parametric alternative that does not rely on normality assumptions. Because the choice between these tests depend on whether the normality assumption holds, we first conducted normality checks using the Shapiro–Wilk test for each BAC variable in both regions. The results showed that most of the BAC variables significantly deviated from normality, indicating skewness and the presence of outliers (Table !0). Based on this, the Mann–Whitney U test was selected as the appropriate method for comparing BAC values between the two regions.

Table 10 Shapiro–Wilk Normality Test Results for BAC

Variable	Region	Obs	W	z	p-value	Normality?
Pb	Ashanti	17	0.932	0.724	0.2344	Normal ($p > 0.05$)
Pb	Eastern	34	0.935	1.722	0.0426	Not normal ($p < 0.05$)
As	Ashanti	17	0.887	1.735	0.0413	Not normal
As	Eastern	34	0.856	3.372	0.0004	Not normal
Cu	Ashanti	17	0.883	1.802	0.0358	Not normal
Cu	Eastern	34	0.266	6.759	0.0000	Not normal
Cd	Ashanti	17	0.564	4.426	0.0000	Not normal
Cd	Eastern	34	0.549	5.743	0.0000	Not normal
Hg	Ashanti	17	0.813	2.737	0.0031	Not normal
Hg	Eastern	34	0.794	4.113	0.0000	Not normal

Because the BAC concentration data were not normally distributed and contained extreme values , we employed the Mann–Whitney U test (Wilcoxon rank-sum test) as a non-parametric alternative to the independent samples t-test (Table 11). This test was appropriate for comparing two independent groups when the normality assumption was violated, as it compared the rank distributions rather than the raw means.

The Mann-Whitney U test analysis revealed no statistically significant differences in bioaccumulation coefficient (BAC) values between medicinal plants from the Ashanti and Eastern Regions across all five heavy metals examined (Pb, As, Cu, Cd, and Hg) (Table 11). This finding warrants careful interpretation within the context of environmental contamination patterns and plant uptake mechanisms.

The non-parametric analysis included fifty-one (51) medicinal plant samples (17 from Ashanti Region and 34 from Eastern Region) and consistently showed p-values well above the significance threshold of 0.05. Lead exhibited the strongest tendency toward regional difference ($Z = -1.372$, $p = 0.1700$), followed by Cd ($Z = -0.943$, $p = 0.3457$), yet neither approached statistical significance. Mercury showed a positive Z-score (1.019), indicating slightly higher BAC values in Ashanti Region compared to Eastern Region, but this difference was not significant ($p = 0.3081$) (Table 11). Arsenic and Cu showed minimal regional variation with very high p-values (0.7949 and 0.8448, respectively) (Table 11).

Table 11 Mann-Whitney U test for difference in BAC values between the two regions

Metal	N (Ashanti)	N (Eastern)	Z-statistic	p-value	Significant (α=0.05)
Pb	17	34	-1.372	0.1700	No
As	17	34	0.260	0.7949	No
Cu	17	34	-0.196	0.8448	No
Cd	17	34	-0.943	0.3457	No
Hg	17	34	1.019	0.3081	No

The Shapiro–Wilk normality tests for Translocation Factor (TF) values revealed that while a few variables in the Ashanti Region (Pb, As, Hg) were approximately normally distributed, most variables—particularly Cu and Cd in Ashanti Region and Pb, Cu, Cd, and Hg in the Eastern Region—significantly deviated from normality (Table 12). These departures, combined with the presence of small sample sizes (e.g., n=5 for Ashanti Region), indicated that the assumption of normal distribution required for parametric tests such as the Independent Samples t-test was not satisfied. Consequently, the Mann–Whitney U test was more appropriate, as it was a non-parametric alternative that did not rely on normality assumptions and instead compared the rank distributions of TF values between the two regions (Table 12).

Table 12 Shapiro–Wilk Normality Test Results for TF

Variable	Region	Obs	W	z	p-value	Normality?
Pb	Ashanti	5	0.889	0.3770	0.3530	Normal ($p > 0.05$)
Pb	Eastern	15	0.577	4.1610	0.00002	Not normal
As	Ashanti	5	0.888	0.3910	0.3480	Normal
As	Eastern	15	0.911	1.0720	0.1418	Normal
Cu	Ashanti	5	0.587	3.34400	0.00041	Not normal
Cu	Eastern	15	0.786	2.8170	0.00242	Not normal
Cd	Ashanti	5	0.741	1.9680	0.0245	Not normal
Cd	Eastern	15	0.532	4.3600	0.00001	Not normal
Hg	Ashanti	5	0.857	0.7780	0.2182	Normal
Hg	Eastern	15	0.544	4.3100	0.00001	Not normal

The Mann–Whitney U test was applied to compare Translocation Factor (TF) values between the Ashanti and Eastern Regions across the five metals (Pb, As, Cu, Cd, Hg) (Table 13). The results indicated that there were no statistically significant differences between the two regions for Pb ($z = –0.920$, $p = 0.357$), As ($z = 0.567$, $p = 0.571$), Cd ($z = –0.044$, $p = 0.965$), or Hg ($z = 1.353$, $p = 0.176$) (Table 13). Copper ($z = 1.878$, $p = 0.060$) showed a borderline difference, but this did not reach the conventional threshold of statistical significance ($\alpha = 0.05$) (Table 13). Overall, these findings suggested that TF distributions for the selected heavy metals were broadly comparable between the Ashanti and Eastern Regions, with no evidence of substantial regional variation.

Table 13 Mann-Whitney U test for difference in TF values between the two regions

Variable	Obs (Ashanti)	Obs (Eastern)	z-statistic	p-value	Significance (α=0.05)
Pb	5	15	-0.920	0.3574	Not significant
As	5	15	0.567	0.5705	Not significant
Cu	5	15	1.878	0.0604	Borderline ($p \approx 0.06$)
Cd	5	15	-0.044	0.9652	Not significant
Hg	5	15	1.353	0.1759	Not significant

The normality test results revealed mixed distributions across the heavy metals, with Pb, As, and Cd showing normal distributions in both regions while Cu and Hg exhibited non-normal distributions in the Eastern Region (Table 14). Although parametric t-tests could theoretically be applied to the normally distributed metals while non-parametric tests handle the non-normal data, this mixed methodological approach would compromise analytical consistency and complicate cross-metal comparisons. The Mann-Whitney U test emerges as the optimal statistical choice because it required no distributional assumptions, handled small sample sizes (5-8 per group) effectively, and provided methodological uniformity across all heavy metals, ensuring robust and interpretable results regardless of underlying data distributions (Table 14).

Table 14 Shapiro–Wilk Normality Test Results for BCF

Variable	Region	Obs	W	z	p-value	Normality?
Pb	Ashanti	5	0.976	-1.343	0.9103	Normal
Pb	Eastern	8	0.872	0.997	0.1593	Normal
As	Ashanti	5	0.815	1.244	0.1068	Normal
As	Eastern	8	0.899	0.575	0.2825	Normal
Cu	Ashanti	5	0.883	0.457	0.3238	Normal
Cu	Eastern	8	0.629	3.394	0.0003	Not normal
Cd	Ashanti	5	0.987	-1.846	0.9675	Normal
Cd	Eastern	8	0.995	-3.209	0.9993	Normal
Hg	Ashanti	5	0.917	-0.019	0.5078	Normal
Hg	Eastern	8	0.634	3.356	0.0004	Not normal

The Mann–Whitney U test was conducted to evaluate potential differences in bioconcentration factor (BCF) values between the Ashanti and Eastern Regions across the five metals (Pb, As, Cu, Cd, Hg) (Table 15). The results revealed no statistically significant differences between the two regions for Pb ($z = –0.881$, $p = 0.379$), As ($z = –0.661$, $p = 0.509$), Cu ($z = –0.548$, $p = 0.584$), Cd ($z = 0.230$, $p = 0.818$), or Hg ($z = –1.610$, $p = 0.107$) (Table 15). While mercury showed a comparatively lower p-value, it did not meet the conventional 5% significance threshold. These findings indicated that the BCF distributions of the analyzed heavy metals were broadly similar in medicinal plants from both regions, with no evidence of significant regional variation.

Table 15 Mann-Whitney U test for difference in BCF values between the two regions

Variable	Obs (Ashanti)	Obs (Eastern)	z-statistic	p-value	Significance (α=0.05)
Pb	5	8	-0.881	0.3785	Not significant
As	5	8	-0.661	0.5089	Not significant
Cu	5	8	-0.548	0.5836	Not significant
Cd	5	8	0.230	0.8182	Not significant
Hg	5	8	-1.610	0.1073	Not significant

Conclusion

The mean levels of hazardous metals in soils evaluated were within the normal range of the respective metals apart from cadmium.The hazardous metals content in the medicinal plants were also in the normal levels except Hg. The TF contents determined showed most of the medicinal plants from Ashanti Region demonstrating high phytoextractive potential for As, Cu, Cd, and Hg whereas most of the medicinal plants from Eastern Region showed phytoextractive potential for As, Cu and Hg.The calculated BCF for medicinal plants for the two regions revealed no phytoextractive potential for Pb, As, Cu and Cd except Hg. The BAC evaluated demonstrated the medicinal plants exhibited no phytoextractive characteristics for Pb, As, Cu, Cd except Hg. There were no significance difference in the TF, BCF and BAC levels for the medicinal plants from Eastern and Ashanti Regions.

Acknowledgements

The author expresses his sincere gratitude to the SHEATHE project http://www.sheathe.org at Chemistry Department, Kwame Nkrumah University of Science and Technology, (KNUST), Kumasi, Ghana for permitting me to analyze my samples in their laboratory.

Author's contribution

The study originated from the author except the statistical Analysis which was performed by Mr John Anamboi.

Funding

No funding was received from any institution.

Data Availability

This work did not include the analysis of any database.

Declarations

Competing interest

The author declare no competing interest

Author Biography

Associate Professor Kofi Sarpong is a Natural Product Chemist trained at Kwame Nkrumah University of Science and Technology, Kumasi. He is a researcher, professional teacher and a leader. He teaches chemistry at both undergraduate and postgraduate levels. He currently teaches at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), Kumasi. He worked as a Research Scientist at Centre for Plant Medicine Research (CPMR), Akuapem-Mampong, Centre for Scientific and Industrial Research (CSIR) – Forestry Research Institute of Ghana (CSIR-FORIG), Kumasi, Juaben Senior High School, Juaben – Ashanti Region, Seventh Day Adventist Senior High School, Bantama-Kumasi, Chirapatre M/A Junior High School, Chirapatre, Kumasi and Esreso Junior High School, Esreso-Bosomtwe District,Ashanti Region. He has expertise in Bioassay Guided Fractionation, Standardization of Herbal Drugs, Encapsulation of Herbal Drugs, Screening for Phytoconstituents, Isolation and Characterization of Novel Phytoconstituents, Screening of Plants for Toxic Chemicals (CPMR), Screening Plants for their Pesticidal Properties (CSIR-FORIG), Analysis of

Wood and Lesser Known Wood Species (CSIR-FORIG) for their durable properties, Analysis of ecosystem for hazardous metals. A reputable teacher in Chemistry and Integrated Science at tertiary institutions and Ghana Education Service (GES).

References

1. Hameed, M., Dijoo, Z.K., Bhat, R.A., & Qayoom, I. (2020). Concerns and Threats of Heavy Metals' Contamination on Aquatic Ecosystem. Bioremediation and Biotechnology, 4, 1-19. https://doi.org/10.1007/978-3-030-48690-7_1.
2. Lee,, S-H., Kim, S-O., Lee, S-W., Kim, M-S., & Park, H. (2021). Sustainable Remediatio and Reuse of Remediated Soil. Sustainability, 13 (22), 12523. https://doi.org/10.3390/54132212523.
3. Leon, O.L., & Pacheco, J.M.S. (2020). Effects of Lead on Reproductive Health. IntechOpen 1-20. https://dx.doi.org/10.5772/Intechopen.91992.
4. Sarpong, K. (2025). Contents and Human Health Risk Assessment of Hazardous Metals in Decoctions from Ashanti Region, Ghana. International Journal of Green and Herbal Chemistry 14 (3), 385-408. https://doi:10.24214/IJGHC/GC14/3/38508.
5. Michael, A. (2023). Heavy Metals in Soil: A Review. Chem Eng Process Tech, 8 (1),1076.
6. Fazekasova, D., & Fazekas, J. (2019). Functional Diversity of soil microorganisms in the conditions of an ecological farming system. Folia Oecol., 46,146-152.
7. Li. C., Zhou, K., Qin, W., Tian, C., Qi, M., Yan, X. (2019). A Review on Heavy metal contamination in Soil: Effects, Sources and Remediation Techniques. An Int., 28, 380-394.
8. Martinez, V. D., Vucic, E.A., Becker-Santos, D.D., Gil, L., & Lam, W.L. (2011). Arsenic Exposure and the Induction of Human Cancers. Journal of Toxicology, 2011, 13 pages. https://doi:10.1155/2011/431287.
9. Braver-Sewradj, S.A., Benthem, J., Staal, Y.C.M., Ezendam, J., Piersma, A.H. & Hessel, E.V.S. (2021).Occupational exposure to hexavalent chromium. Part II. Hazard assessment of carcinogenic effects. Regulatory Toxicology and Pharcology, 126, 105045. https://doi.org/10.1016/j.yrtph.2021.105045.
10. Rana, M.N., Tangpong, J., & Rahman, M.M. (2018). Toxicodynamics of Lead, Cadmium, Mercury and Arsenic-induced kidney toxicity and treatment strategy: A smini review. Toxicology Reports, 5, 704-713. https://doi.org/10.1016/j.toxrep.2018.05.012.
11. Kim, D-W., Ock, J., Moon, K-W., & Park, C-H. (2021). Association between Pb, Cd and Hg Exposure and Liver INJURY among Korean Adults. Int. J. Environ. Res. Public Health, 18, 6783.https://doi.org/10.3390/ijerph18136783.
12. World Health Organization (WHO)(2024). Lead poisoning, Key Facts.
13. Kramer, U.(2010) Metal hyperaccumulation in plants. Annual Review in Plant Biology 61: 517-534.
14. Yoon, J., Cao, X., Zhou, Q., & Ma, L.Q. (2006). Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment, 368 (2-3), 456-46.
15. Li, M.S., Luo, Y.P., & Su, Z.Y. (2007). Heavy metal Concentrations in Soils and Plant accumulation in restored manganese in Guangxi, South China. Environmental Pollution, 147,168-175.
16. Cui, S., Zhou, Q., & Chao, L. (2007). Potential hyperaccumulation of Pb. Zn, Cu and Cd in endurant plants distributed in an old smeltery, northeast China. Environmental Geology, 51. 1043-1048.

17. Zand, A.D., Tabrizi, A.M., & Heir, A. V. (2020). Incorporation of biochar and nanomaterials to assist remediation of heavy metals in soil using plant species. Environmental Technology & Innovation, 20,101134.
18. Fitz, W.J., & Wenzel, W.W. (2002). Arsenic transformations in the soil–rhizosphere–plant system: fundamentals and potential application to phytoremediation. Journal of biotechnology, 99(3), 259-278.
19. Mendez, M.O., & Maier, R.M. (2008) Phytostabilization of mine tailings in arid and semiarid environments—an emerging remediation technology. Environmental health perspectives, 116(3), 278 -283.
20. Petelka, J., Abraham, J., Bockreis, A.,, Deikumah, J.P., & Zerbe, S. (2019). Soil Heavy Metal(loid) Pollution and Phytoremediation Potential of Native Plants on Former Gold Mine in Ghana. Water And Soil Pollut., 230, 267. https://doi.org/10.1007/s11270-019-4317- 4.
21. Sarpong, K., & Dartey, E (2017). Assessment of hazardous metal load in soils and medicinal plants samples from Suame Magazine, Kumasi. Journal of Medicinal Plants Research, 6(6), 355-362.
22. Wuana, R.A., & Okieimen, F.E. (2011). Heavy Metals in Contaminated Soils:A Review of Sources,Chemistry, Risks and Best Available Strategies for Remediation. Communications in Soil Science and Plant Analysis, 42, 111-122.https://dx.doi.org/10.5402/2011/402647.
23. Kabata-Pendias, A. (2011). Trace Elements in Soils and Plants (4th ed.). Boca Raton, FL: CRC Press. https://doi.org/10.1201/b10158.
24. Natasha, Shahid, M., Khalid, S., Bibi, I., Bundschuh, J., Niazi, N.K., & Dumat, C. (2020). A critical review of mercury speciation, bioavailability, detoxification in soil-plant environment: Ecotoxicology and health risk assessment. Science of Total Environment, 711, 134749.https://doi.org/10.1016/j.scitotenv.2019.134749.
25. Assad, M., Parelle, J., Cazaux, D,, Gimbert, F., Chalot, M., & Tatin-Froux, F. (2019). Mercury uptake into popular leaves. Chemosphere, 146, 1-7.https://doi.org/10.1016/j.chemosphere.2015.11.103.
26. Ahammad, S.J., Sumithra, S., & Senthilkumar, P. (2018). Mercury uptake and translocation by indigenous plants. Rasayan J. Chem., 11, 1-12. https://doi.org/10.7324/RJC.2018.1111726.
27. Sarpong, K. (2025). Contents and Human Health Risk Assessment of Hazardous Metals in Decoctions from Ashanti Region, Ghana. International Journal of Green and Herbal Chemistry, Section A: Green Chemistry, 14(3), 385-408.
28. US EPA, Method 6200 (2007). Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment Method: 6200. https:// epa.gov/sites/production/files/2015-12/documents/6200.pdf.(Accessed: 2nd June 2025).
29. Akoto, O., Bortey-Sam, N., Ikenaka, Y., Nakayama, S.M.M., Baidoo, E., Yohannes,Y.B., & Ishizuka, M. (2017). Contamination Levels and Sources of Heavy Metals and a Metalloid in Surface Soils in the Kumasi Metropolis, Ghana. Journal of Health & Pollution, 15, 28-39.
30. Zand, A.D., Tabrizi, A.M., & Heir, A.V. (2020). Incorporation of biochar and nanomaterials to assist remediation of heavy metals in soil using plant species. Environmental Technology & Innovation 20, 101134.
31. Feng, G., Xie, T., Wang, X., Bai, J,, Tang, L., Zhao, H., Wei, W., Wang, M. & Zhao, Y. (2018) Metagenomic analysis of microbial community and function involved in cdcontaminated soil. BMC microbiology,18(1), 1-13.

32. Nazir, A., Malik, R.N., Ajaib, M., Khan, N. & Siddique, M.A (2011). Hyperaccumulators of heavy metals of industrial areas of Islamabad and Rawalpindi. Pak. J. Bot., 43 (4), 1925-1933.
33. Porter, J.A., Wolbach, K.C., Purzycki, C.B., Bowman, L.A., Agbada, E. & Mostrom, A.M.J.C.L.S.E. (2010). Integration of information and scientific literacy: Promoting literacy in undergraduates, 9(4), 536-542.
34. Sarpong, K., Acheampong, A., Darko, G. & Akoto, O. (2022). Potentially toxic Metal Loads in Soils Supporting Medicinal Plants in the Ashanti Region of Ghana. Chemistry Africa https://doi.org/10.1007/s42250-022-00341-4
35. Acheampong, A., Sarpong, K., Akoto, O., Apau, J., & Darko, G. (2024). Health Risk Assessment of Potentially Toxic Elements in Selected Medicinal Plants from the Ashanti Region of Ghana. Chemistry Africa, 1-19.
36. Sarpong, K. & Dartey, E. (2017). Assessment of Hazardous metal load in soils and medicinal plants samples from Suame Magazine, Kumasi. International Journal of Medicinal Plants, 6(6), 355-3
37. Nieder, R. & Benbi, D. (2023). Potentially toxic elements in the environment - a review of sources,sinks, pathways and mitigation measures. Reviews on Environmental Health, 39 (3). https://doi:10.1515/reveh-2022-0161