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Heavy metals in medicinal plant products — An African perspective

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Abstract

Heavy metal toxicity related to the use of traditional medicines has been reported worldwide. Heavy metals may be introduced into medicinal plant products through contaminated agricultural resources and/or poor production practices. Deliberate addition of heavy metals for alleged medicinal value has been documented in numerous cultural groups. Poisoning from heavy metal contamination of medicinal plant products has caused countless health implications including liver and kidney failure and even death. African natural plant-based products have evolved to incorporate various synthetic products such as heavy metals for alleged medicinal properties. This review emphasizes the main areas in agriculture and production where contamination may occur. At the same time it highlights the cultural uses and poisonings related to heavy metals in traditional medicines. Adequate regulatory measures and quality control of African herbal products for toxic heavy metals are required.

Keywords: Contamination; Heavy metals; Traditional medicine; Herbal products; Medicinal plants

1. Introduction

Heavy metals of non-anthropogenic origin are always present at a background level with their occurrence in soils being related to weathering of parent rocks and pedogenesis (Ghiyasi et al., 2010). However the concentration of several heavy metals has increased dramatically in certain ecosystems due to anthropogenic activities (Sarma et al., 2012). Heavy metals frequently occur as cations which strongly interact with the soil matrix and can become mobile as a result of changing environmental conditions (Qishlaqi and Farid Moore, 2007). Plants can amass trace elements, especially heavy metals, in and on their tissues due to their ability to tolerate potentially toxic ions in the environment (Kabata-pendias, 2001). Heavy metal uptake by plants can increase the potential of certain toxic elements entering the food chain thus understanding how these elements progress through food webs, and the effects of such elements on organisms, is the topic of considerable interest (Boyd, 2009).

The adverse effects of heavy metals on human health have been known for a long time nevertheless exposure to heavy metals continues and is even increasing in some areas (Jarup, 2003; Kaushik et al., 2009). Due to the high prevalence of heavy metals in the environment, their residues also reach and are assimilated into medicinal plants (Sarma et al., 2012). There are three key mechanisms that have been proposed to explain heavy metal contamination of medical plant-based products; contamination during cultivation, inadvertent cross-contamination during processing and/or the purposeful introduction of heavy metals for alleged medicinal purposes (Denholm, 2010). The research presented in this paper reviews the various sources of heavy metal contamination, the effect on medicinal plant quality as well as highlights adverse effects to humans.

2. Heavy metal accumulation by medicinal plants

There is now extensive interest in heavy metal transport by metal-tolerant plants (metallophytes) because of the repercussions for phytoremediation (Iqbnal Lone et al., 2008; Sarma, 2011). The use of plants to remediate polluted soils is seen as having great promise compared to conventional, civil-engineering methods (Rascio and Navari-Izzo, 2011). A copious number of plants have been explored for phytoremediation (Padmavathiamma and Li, 2007; Sarma, 2011) however the accumulation of heavy metals in edible and medicinal plants need thorough investigation to prevent elevated concentrations of

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heavy metals reaching the consumer (Sharma et al., 2009; Steenkamp et al., 2000). Heavy metal origin and content as well as their possible interaction with soil properties are priority objectives in environmental monitoring (Qishlaqi and Farid Moore, 2007). This is due to the fact that apart from the source of heavy metals, the physicochemical properties of soil may also affect the heavy metal concentration (Aydinalp and Marinova, 2003; Qishlaqi and Farid Moore, 2007). Numerous abiotic factors influence the availability of metal to plants including pH, temperature, redox potential, cation exchange capacity and organic matter (Gregor, 2004). Furthermore, the interactions of soil-plant roots-microbes play vital roles in regulating heavy metal movement from the soil to edible plant parts (Islam et al., 2007). The accumulation of metals by both roots and leaves increases with increasing available metal concentration in the external medium (Gregor, 2004). Factors such as reduced biomass, root length and shoot length are common indicators of heavy metal toxicity (Houshmandfar and Moraghebi, 2011; Siddhu et al., 2008). Changes at the cell, tissue and organ level are either a result of a direct interaction between the metal and structural components at the sites or a consequence of changes in signal transduction and/or metabolism (Solanki and Dhankhar, 2011). Plant responses to heavy metals should be investigated for the particular soil-plant environment (Kabata-pendias, 2001). The term “hyperaccumulator” describes plant species that have the ability to grow on metalliferous soils and to accumulate extraordinarily high levels of heavy metals (in comparison to the majority of species) without displaying phytotoxic effects (Rascio and Navari-Izzo, 2011). However hyperaccumulators are habitually confined to metal-enriched soils such as those soils found on serpentine outcrops and other metalliferous rocks (Reeves, 2002).

Numerous medicinal plants have the ability to accumulate heavy metals when grown under natural conditions. Medicinally used *Senecio coronatus* (Thunb.) Harv. (Asteraceae) is one of the nine nickel (Ni) hyperaccumulating plants in Africa (Przybylowics et al., 1995). Similarly, two African medicinally used *Datura* species are metallophytes namely *Datura metal* L. (Solanaceae), an accumulator of cobalt (Co) and Ni and recommended as a phytomonitor (Bhattacharjee et al., 2004), and *Datura innoxia* Miller, Gard., a metal tolerant species (Kelly et al., 2002). Likewise *Helichrysum candolleanum* H. Buek (Asteraceae) and *Blepharis diversispina* (Nees) C.B.Clarke (Acanthaceae) are also able to tolerate high concentrations of metals (Nkoane et al., 2005). The levels of heavy metals in 27 medicinal plant species collected from their natural habitat in Ghana were studied in order to evaluate their health implications (Annan et al., 2010). Cadmium (Cd) was present in all samples and some species, especially *Ocimum canum* (Lamiaceae), *Clausena anisata* (Rutaceae) and *Rauwolfia vomitoria* (Apocynaceae) had levels of iron (Fe) which could cause Fe toxicity. Despite the popular use of the above mentioned African medicinal plant species, ongoing evaluation of heavy metal uptake by these species with regards to consumer safety is not considered.

Cultivation of medicinal plants, as opposed to collection from the wild, will allow for controlled growth and monitoring of potentially hazardous parameters (Canter et al., 2005; Sparg et al., 2005). Nonetheless many agro-chemicals contain heavy metals such as Cd and lead (Pb) which enter the soil due to fertiliser impurities thus heavy metal contamination in soils is often caused by repeated use of metal-enriched fertilisers (He et al., 2004). As a result soil and water sources (both primary and secondary) need to be monitored periodically under Good Agricultural and Collection Practice (GACP). This is the first phase in good quality assurance upon which the safety and efficacy of plant-based medicinal products directly depend (WHO, 2003). Site selection should be based on contaminant free soil and irrigation supply. So far only the European Union and a few other countries, such as China and Japan have developed regional specific and national guidelines for GACP for medicinal plants (WHO, 2003). Such guidelines are regulated and monitored to make certain that the correct plant material is collected and/or cultivated and that soil and irrigation water are within the limits, or free from, unsafe heavy metals and toxicologically hazardous substances. In developing countries, regulations such as GACP are infrequently implemented and rarely enforced.

3. Effect of heavy metals on secondary metabolites

Mineral elements are involved in the structure of some secondary metabolites, yet can also have undesirable effects on their regulation (Poutaraud and Girardin, 2005). Nonetheless, few studies have addressed the effects of heavy metals on the ultramorphological characteristics and the therapeutically active constituents in medicinal plant parts (Nasim and Dhir, 2010). Plants exposed to heavy metal stress show varying degrees of secondary metabolite response (Table 1). Chromium (Cr)-stress induced the production of eugenol, a major component of essential oil of *Ocimum tenuiflorum* (Lamiaceae) (15, 25, 17, 4% more eugenol from 10, 20, 50 and 100 μM Cr exposed plants, respectively) (Rai et al., 2004). Similarly the therapeutically active compounds, phyllanthin and hypophyllanthin, were enhanced at certain levels of Cd stress in *Phyllanthus amarus* Schum and Thonn (Phyllanthaceae). On the contrary, heavy metal pollution of soil and air at a distance of 400 m from the source of pollution suppressed the growth of *Mentha piperita* L. (c v T u n d z a and C l o n e No 1) (Lamiaceae) and *Mentha arvensis* var piperascens Ma l inv. (c v Me n t o l n a - 1 4) and the yield of essential oil by up to 14% compared to the control. This however did not negatively affect the essential oil content and its quality (Zheljazkov and Nielsen, 1996). It is debatable whether screening medicinal plants by means of *in vitro* assays is the most effective approach to validation (Verpoorte, 1998) though, in Africa, the active compound(s) of so few medicinal plants have been identified that simply screening of medicinal plant extracts using biological assays is the norm (Jäger and Van Staden, 2005; Light et al., 2005). Nevertheless reporting on biological activity of crude plant extracts without the isolation and identification of an active compound raises concern, as the activity may be due to the presence of toxic substances (Elgorashi et al., 2004). A recent study investigated Cd accumulation and its effect on COX-1 and COX-2 anti-inflammatory activity in *Eucomis autumnalis* (Hyacinthaceae) and *Eucomis humilis* (Street et al., 2009). When treated with Cd 2 mg L^{-1}, *E. humilis* bulbous extracts

Table 1
Examples of studies on heavy metal stress affecting secondary metabolite production.

Plant species	Main findings relating to secondary metabolites	Reference
Hypericum perforatum L.	• In the presence of Ni, the plant completely lost the ability to produce or accumulate hyperforin and demonstrated a 15–20-fold decrease in the concentration of pseudohypericin and hypericin	Murch et al., 2003
Ocimum tenuiflorum L.	• Cr stress induced the production of eugenol	Rai et al., 2004
Dioscorea bulbifera L.	• The occurrence of Cu stimulated diosgenin production	Narula et al., 2005
Phyllanthus amarus Schum. and Thonn	• Phyllanthin and hypophyllanthin was enhanced by Cd stress	Rai et al., 2005
Bacopa monnieri L.	• The level of bacoside-A increased due to increased Fe in the media	Sinha and Saxena, 2006
Trigonella foenum-graecum L.	• Cd and Co increased diosgenin levels however Cr and Ni inhibited its production	De and De, 2011

exhibited lower inhibitory activity than the control for both COX-1 and COX-2 whilst *E. autumnalis* bulbous extracts had greater COX-1 activity compared to the control with suppressed COX-2 activity. The study cautioned researchers to be cognizant of the consequence of environmental contaminants when reporting on biological activity of crude plant extracts.

It is clear that heavy metal induced stimulation of medicinal plants is strongly influenced by several aspects including plant growth stage, concentration and duration of treatment, and composition of growth medium (Nasim and Dhir, 2010; Rajakaruna et al., 2002). As a result optimizing nutrient supply is a key factor in the quality of medicinal plants. It has been suggested that certain medicinal plants be grown in polluted soils for higher secondary metabolite yield (Rai et al., 2004) this will however depend on the plant part used as consumer safety needs to be first and foremost.

4. Heavy metals in medicinal plants and plant-based products

Numerous studies have been conducted worldwide to determine heavy metal levels in medicinal plants and plant-based products (Annan et al., 2010; Ebrahim et al., 2012; Maharia et al., 2010). Both developed and developing countries have shown high levels of potentially toxic heavy metals in products available to the public (Denholm, 2010; Garvey et al., 2001). Such products are not only from local sources but are often imported (Saper et al., 2008). A study examining heavy metal content in traditional Asian herbal remedies purchased in the United States, Vietnam and China revealed that the majority of products had detectable levels of heavy metals, with nearly 74% containing amounts greater than current recommended public health guidelines (Garvey et al., 2001). An effective solution to the importation of traditional medicines containing heavy metals presents a great challenge (Shaw, 1998; Saper et al., 2008). These products are expected to be imported in small quantities by numerous different routes, including via the postal service and with intercontinental travelers (Denholm, 2010). Formal labeling and packaging may be deceptive as it gives the public a false sense of product safety.

In Africa, formalization and registration of herbal products are not the norm and preparations often lack appropriate labeling such as contents, contraindications, place and date of manufacture and expiry date. Medicinal plant collection is often from the wild and locations are habitually undisclosed. Thus the traceability of medicinal plants which are sold at traditional medicine markets is nonexistent. A study by Street et al. (2008) showed that South African medicinal plant parts harvested from a wide range of undisclosed locations by plant gatherers and sold at informal markets had multiple metal contamination. Lead and Ni were detected in all samples and elevated Fe and manganese (Mn) contents were recorded in certain plant species. The only way to ensure consumer safety is to periodically sample plants from the traditional medicine markets however even this is complicated due to the fact that plants of the same species are habitually collected from various sources and are added together in one storage container. It is nonetheless imperative that medicinal plants are tested for metal contamination as these plants are used as starting material for numerous herbal products. Correct post-harvest processing may also contribute to the minimization of heavy metals in the starting materials. A study by Abou-Arab and Abou Donia (2000) investigated Egyptian medicinal plants processed by two different methods to determine the behavior of their metal contents during processing. In general, boiling the plants in water led to extraction of higher amounts of the metal from the plant than submerging them in hot water however the investigated metals were transferred from the plant tissue into the used water at different ratios depending on the metal, the plant, and the method of extraction. A study regarding the concentration of arsenic (As), Cd, Pb and mercury (Hg) in 20 registered ready to use herbal products purchased randomly from the pharmacy shops in Lagos (Nigeria) revealed that none of the samples contained detectable Pb; however, all the samples contained a detectable quantity of one or more of the other metals of interest (Adepoju-Bello et al., 2012). Despite studies conducted to determine heavy metal levels in African medicinal plants and plant-based products (Table 2), with no regulatory guidelines or methods of enforcing limits, these studies simply illustrate the potential to cause hazard to human health without any resolve.

5. Intentional uses of heavy metals for medicinal purposes

Heavy metals are a regular and deliberate component of traditional remedies worldwide therefore the use of the term ‘contamination’ with respect to the occurrence of heavy metals in traditional remedies is disingenuous (Ernst, 2002). In traditional Chinese medicine, heavy metals have been used for numerous health complaints. For example, Hg is part of certain preparations under the terminology of ‘cinnabaris’ (mercury sulfide), ‘calomel’ (mercury chloride) or ‘hydrargyri oxydum rubrum’ (mercury oxide) (Ernst, 2002). Allopathic medical practitioners are skeptical

Table 2
Examples of heavy metal assessment of medicinal plant products from Africa.

Country	Elements assessed	Reference
Egypt	Cd, Co, Cr, Cu, Pb, Ni, Mn, Fe, Sn, Zn	Abou-Arab and Abou Donia, 2000
Egypt	Cd, Cu, Pb	Dogheim et al., 2004
Egypt	Ca, Cu, Mg, Mn, Fe, K, Na, Se, Zn	Sheded et al., 2006
Ghana	Al, Br, Ca, Cl, Co, Cu, Cr, K, Mn, Mg, Na, Rb, Sb, Sc, Ta, V, Zn	Serfor-Armay et al., 2002
Ghana	Cd, Cu, Fe, Mn, Ni, Zn	Annan et al., 2010
Mali	Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn	Maiga et al., 2005
Nigeria	Ca, Cu, Mn, Mg, K, Fe, Pb, Zn	Ajasa et al., 2004
Nigeria	Cd, Cu, Fe, Ni, Se, Zn, Pb, Hg	Obi et al., 2006
Nigeria	Ca, Cd, Cr, Fe, K, Mn, Na, Mg, P, Pb, Zn	Abolaji et al., 2007
South Africa	Cu, Pb, Mn, Hg, Se, Zn	Steenkamp et al., 2000
South Africa	U	Steenkamp et al., 2005
Sudan	Cd, Cr, Cu, Fe, Hg, Pb, Mn, Mg, Se, Sn, Zn	Ebrahim et al., 2012

about the use of Hg for therapy — a perception not supported by traditional medicine practitioners (Kamath et al., 2012). In Indian traditional medicine, otherwise known as ayurveda, bhasma (calcified powder/ash) are herbo-mineral or herbo-metallic formulations. The segment of ayurveda which involves bhasma is referred to as ‘Rasa Sastra’. Buddhist Philosopher Nagarjuna who was deemed the father of metallic medicine in India used metals and minerals in the form of bhasma as remedial agents from preceding 8th century A.D (Senthil Kumar et al., 2011). Metals mixed with organic compounds derived from plant extracts render them biocompatible according to ancient traditions (Kamath et al., 2012; Senthil Kumar et al., 2011). Recent studies have shown the scientific processes behind the detoxification of metals during processing of such herbo-metallic formulations (Kamath et al., 2012). Although heavy metal salts are an additive of African traditional medicines, no such epistemology has been documented to explain the alleviation of potentially toxic substances. However this is not to say that such a theory does not exist.

While heavy metals have been detected in African traditional remedies (Table 2) few studies have documented the commonly available metals used in African traditional medicine or investigated the reason behind such usage. Hexavalent chromium (Cr(VI), a class 1 carcinogen, is commonly used in South African traditional medicines and known locally as *ndonya*. A study by Sewram et al. (2010) revealed that 72% of traditional health practitioners (n = 395) prescribed *ndonya*-containing medicines for healing purposes. A large number (50%) admitted to substituting *ndonya* with copper sulphate crystals if *ndonya* was not available. The issue of toxicity depended on method of preparation and mode of administration whilst the pharmacological effects were said to be altered by the food eaten as well as individual tolerance. The concentration of Cr(VI) in traditional medicine preparations varied considerably from 4 μg/L–53 g/L. Such results are cause for concern and warrants toxicity awareness.

6. Poisoning from heavy metal contamination of traditional medicine products

Medicinal plants have been shown to be both a rich source of essential metal ions and a potentially dangerous source of non-essential metals (Narendhirakannan et al., 2005; Singh and Garg, 1997). Poisonings from traditional medicine products containing heavy metals is well documented (Dargan et al., 2008; Ernst, 2002). The toxic effects of heavy metals are due to their hindrance with the regular body biochemistry in normal metabolic processes (Duruibe et al., 2007). Arsenic, Cr and magnesium (Mg) are the heavy metals most frequently implicated in morbidity and death in South Africa (Steenkamp et al., 2002). An investigation of the Johannesburg forensic record over a period of 5 years (1991–1995) identified 206 cases in which a traditional remedy was either declared to be the grounds for death or was found to be present in a case of poisoning with an unidentified substance (Stewart et al., 1999). Heavy metals were responsible for 10% of these poisonings. A study by Steenkamp et al. (2000) on heavy metal concentrations in plants, plant-based remedies and urine from patients treated with traditional remedies concluded that out of the 12 concoctions investigated, copper (Cu) levels were extremely high in 4 of the concoctions. A large number of patients (34%) showed elevated zinc (Zn) concentrations. In one of the patients the Zn concentration was 10 times the upper limit of the reference range. After a week of vomiting with hepatomegaly, and dehydration, the patient died of hepatic failure. A further report revealed that a seven month old infant was hospitalised after the intake of a traditional medicine which resulted in a severe case of multiple metal poisoning (Steenkamp et al., 2002). It is known that numerous traditional medicines give rise to severe renal pathology, the mechanism of which is uncertain but which could be associated with heavy metal toxicity (Steenkamp et al., 2000). It has been suggested that potassium dichromate ($K_2Cr_2O_7$) toxicity should be suspected in cases of unexplained renal failure (Woods et al., 1990). Woods et al. (1990) reported seven cases of dichromate poisoning after the use of purgative solutions obtained from traditional healers. One patient who ingested dichromate died from massive gastro-intestinal hemorrhage. Six patients took dichromate solutions as rectal enemas, two were left with impaired renal function and one patient required a permanent colostomy caused by extensive peri-anal necrosis. Similar reports have indicated that Cr(VI)-containing traditional remedies have been the cause of poisonings and morbidity in young children (Steenkamp et al., 2002). In Nigeria, a study reported high levels of heavy metal in blood from unknown sources (Ibeto and Okoye, 2010) and the introduction from African traditional medicines cannot be ruled out.

Unfortunately customarily African traditional medicine products do not contain details such as place of production/manufacture thus there is no accountability for adverse reactions. Strict regulations with regard to classification and labelling may prevent further poisonings. Moreover, certain substances should not be available to the general public for self-administration such as $K_2Cr_2O_7$. Regrettably adverse reactions and poisoning profile of traditional medicine is not well documented and substances are often inadequately categorised. For example, potassium permanganate which could be classified as a household chemical or antiseptic is also used in South African traditional medicine however this substance may be incorrectly profiled with regards to causative agents in acute and chronic poisonings (Balme et al., 2012).

7. International standards regarding heavy metals in traditional medicines

Health, safety and quality declarations are key features with respect to regulatory requirements and standards globally. However, there are immense discrepancies between countries regarding regulatory requirements to pledge safety and quality of plant-based products (Diederichs et al., 2006). Several regulations have already been established worldwide for medicinal plants and related marketed herbal products such as the US Pharmacopoeia (USP), Italian Pharmacopoeia (FUI), and European Pharmacopoeia (Ph. Eur.). Moreover, there are legal frameworks at national and/or regional levels that are designed to regulate the quality of plant-based products (Sarma et al., 2012). Before 1988, only 14 WHO Member States had regulations relating to herbal medicine products but by 2003, this had increased to 53 Member States (37%). Of those without laws/regulations, 49% declared that such regulations were in the process of being developed (WHO, 2005). Several countries, including Canada, China, Malaysia, Singapore and Thailand, have developed their own national guidelines to ensure satisfactory levels of heavy metals in medicinal plants and plant-based products (Table 3). The WHO (1998) recommends maximum permissible levels in raw materials for Cd and Pb which amount to 0.3 and 10 mg kg^{-1}, respectively. Even though certain essential elements can be toxic at high levels; the WHO limits for these metals have not yet been established.

8. Conclusion

Heavy metals may enter medicinal plant-based remedies through both intentional and unintentional routes (Annan et al., 2010; Senthil Kumar et al., 2011). The external appearance of medicinal plants cannot guarantee safety from contamination especially when farming activities are carried out around contaminated areas (Olowoyo et al., 2012). Reliance on plants collected from the wild causes not only a threat to medicinal plant biodiversity (Grace, 2011) but also conjecture with regards to safety, as industrial encroachment has led to contamination of water tables and soil (Zhuang et al., 2009). Conscious site selection coupled with suitable soil management can reduce heavy metal uptake by medicinal plants (Chaiyarat et al., 2011).

Controlled growth (under GACP) and processing environments (under Good Manufacturing Practice) need to ensure that heavy metal contamination of medicinal plant material is kept to a minimum. For the medicinal plant industry, cultivated plant material is preferred as it is easier to control the supply chain plus contamination is nominal (Lubbe and Verpoorte, 2011). Numerous studies have shown the effect of heavy metals on plant growth and development of various African medicinal plant species grown under controlled environments (Lux et al., 2011; Street et al., 2009) however such studies rarely translate into field trials and therefore do not develop into comprehensive pragmatic guidelines for medicinal plant growers. The influence of heavy metals on secondary metabolite production needs thorough investigation as this may severely affect the quality of the end product (Rai et al., 2004; Zheljazkov and Nielsen, 1996). While the scientific literature regarding heavy metal accumulation in plants and the hazards these elements cause for humans is plentiful, information does not exist about biochemical mechanisms of transfer of these elements to primary and secondary consumers (Peralta-Videa et al., 2009). The influence of toxic manifestations includes chemical nature of the metal, route of administration, dosage, residence time within the body, pharmacokinetics and dynamics, bioavailability, metabolic transformations of the preparations, age, gender, physiology, nature and stage of disease and diet (Hung et al., 1997). Therefore careful risk analysis is needed to establish the risk involved in a given preparation (Kamath et al., 2012). Despite availability of metal salts in African traditional markets, information regarding herbometallic preparations is lacking. The combination of raw heavy metals and medicinal plants may alter the cell uptake, distribution

Table 3
Examples of national limits for heavy metals in herbal medicinal products (WHO, 2005).

		Arsenic (As)	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Mercury (Hg)	Copper (Cu)	Lead (Pb)
Canada	Raw herbal materials	5 ppm	10 ppm	0.3 ppm	2 ppm	0.2 ppm		
	Finished herbal products	0.01 mg/day	0.02 mg/day	0.06 mg/day	0.02 mg/day	0.02 mg /day		
China	Herbal materials	2 ppm	10 ppm	1 ppm		0.5 ppm		20 ppm
Malaysia	Finished herbal products	5 mg/kg	10 mg/kg			0.5 mg/kg		
Republic of Korea	Herbal materials							30 ppm
Singapore	Finished herbal products	5 ppm	20 ppm			0.5 ppm	150 ppm	
Thailand	Herbal material, finished herbal products	4 ppm	10 ppm	0.3 ppm				
WHO recommendations			10 mg/kg	0.3 mg/kg				

and elimination profile as well as the therapeutic properties; however no pharmacotherapeutic studies exist to analyse the effect of these herbo-metallic preparations (Kamath et al., 2012). It is imperative that potential risk factors of heavy metal intake from African traditional medicine products be addressed and that regulatory guidelines are not only carefully developed but also enforced.

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