Asian Journal of Water, Environment and Pollution, Vol. 20, No. 6 (2023), pp. 9-17.
DOI 10.3233/AJW230074

Heavy Metal Contamination of Medicinal Plants in India – A Perspective

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Received June 1, 2022; revised and accepted April 6, 2023

Abstract: The presence of heavy metals in medicinal plants (MP) is a matter of serious concern as it directly affects human health. In India, the problem is especially significant since the country is a major consumer as well as exporter of medicinal plant-based raw materials and products. Raw material available in the market is often reported to contain traces of heavy metals and these consequently compromise the quality of medicinal plants-based medicinal formulations. In the present study, the reports of heavy metals in MP from India were collated to ascertain the extent of the problem and highlight the source of contamination. The states with the highest number of metals above permissible limits included Chhattisgarh, Maharashtra, Delhi, Kerala, Karnataka, and Uttar Pradesh. The levels of Cd and Cr metals were found to be the highest in Rajasthan, Odisha, Pb in Kerala and Hg, As in the state of Tamil Nadu. Plants growing in areas having mining activities as well as those growing on urban landscapes such as along roadsides or areas having an inflow of industrial effluents or agricultural run-off showed higher metal content than the standard limit. The presence of metals in natural habitats such as the mangroves and low lands of the Himalayan range was also noted. The review provides an insight into the magnitude of the issue, its causes and the possible lacuna that needs to be addressed to mitigate the problem.

Key words: Heavy metals, medicinal plants, metal contamination.

Introduction

India is recognised as one of the plant mega diversity centres having a rich collection of more than 7000 medicinally important plant species. These medicinal and aromatic plant species are used in the preparation of medicines and their supplements under the traditional Ayurveda, Homeopathy, Unani, Siddha, Rigpa and Folk medicine systems (Anand et al., 2022). Traditional herbal medicines are gaining favour in both developing and developed countries. Medicinal plants (MP) are exported worldwide and are a major revenue earner for the country. Worldwide trade is estimated to be 120 billion US$ and is anticipated to expand to 5 trillion US$ by 2050 (Bhattacharya et al., 2014). However, with the rising popularity of MP-based alternative medicine systems worldwide precious resources are facing tremendous pressure (Sharma and Kala, 2022). According to an estimate, 72% of the MP is collected from the wild (Goraya and Ved, 2017). The quality and efficacy of the MP harvested from the wild varies and influences the quality of MP raw material traded in the markets. The presence of foreign matter, adulterations and microbes, etc. is also noted in material collected from the wild which further affects the therapeutic efficacy of the MP-based medicines (Bisht and Uniyal, 2020). Most significant among foreign matter are heavy metals (HM) and this is a matter of concern as they pose serious health risks to human lives (Asiminicesei et al., 2020). This also causes large-scale rejection of

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the MP raw material and significant economic loss. An estimated 58, 447 MT of herbal raw material is rejected annually due to the low quality and the presence of foreign matter (Bisht et al., 2022). The contamination of HM needs to be scrutinised thoroughly to ensure the safety of the consumers. The present review scrutinises the cases of heavy metal contamination of MP reported from different parts of the Indian subcontinent. It aims to provide a regional perspective on the issue by presenting the current status and threat to MP resources, identification of sources of contamination especially at the level of states and suggesting possible solutions to ensure the quality and efficacy of MP in India.

Heavy Metal Contamination in Medicinal Plants

A brief summary of reports of MP contaminated with heavy metal from different locations in India is presented in Table 1. Cd, Pb, Hg, As, Cr, Zn, Ni, Fe and Cu were the metals found in the plant samples collected from various contaminated sites in different parts of India (Figure 1). The presence of Zn was noted in the majority of cases, followed by Pb, Cr, Cd, and Fe. The states with the highest number of metals above permissible limits included Chhattisgarh, Maharashtra, Delhi, Kerala, Karnataka, and Uttarakhand. With reference to specific metals highest levels of Cd and Cr were detected in samples collected from Rajasthan and Odisha, Pb in Kerala, Hg and As in Tamil Nadu. MP collected from Tamil Nadu was also reported to contain Fe beyond permissible limits (Moscow and Jothivenkatachalam, 2012). A significant level of Cd was reported in MP collected from Karnataka (Teerthe and Kerur, 2015). It is a matter of concern that a major proportion of MP collected from the areas considered to

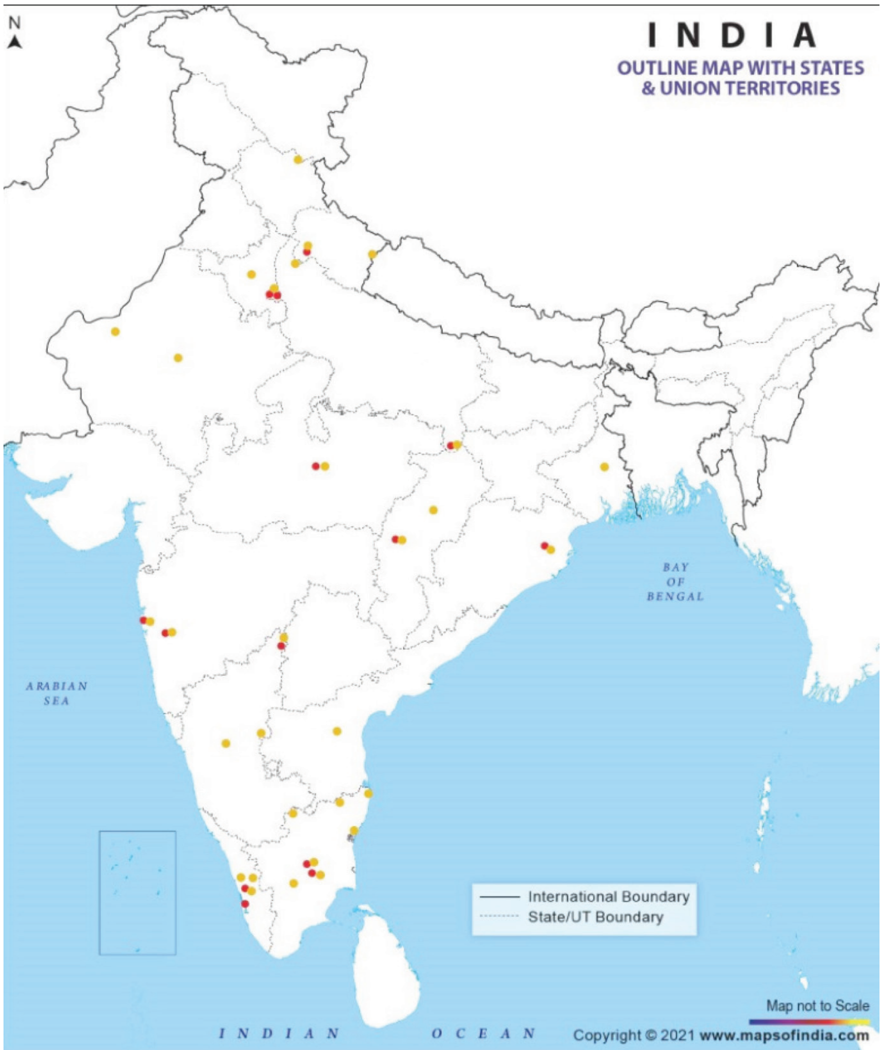

Figure 1: Marks on the map denote the collection sites of medicinal plants as mentioned in the reports collected from published literature (yellow indicates levels within and red beyond permissible levels).

Table 1: Reports of heavy metal contamination in medicinal plants collected from different parts of the country. Possible sources of contamination as mentioned in the reports are also mentioned.The concentrations higher than permissible level have been marked (*)

S.no.	*List of medicinal plants*	*Heavy metal with the range reported*	*Region/State*	*Source of contamination*	*References*
1.	*Azadirachta indica, Cassia fistula Pithecellobium dulce*	Cd*, Cr*, Zn*, Ni*, Cu*, Fe*	Delhi	Fly ash contaminated soils	(Qadir et al., 2021)
2.	*Argemone mexicana, Calotropis procera, Euphorbia hirta, Pteridium latiusculum, Tridax procumbens, Vernonia cinerea*	Cd*, Pb*, Cr*, Ni*	Rajasthan, Odisha	Chromite mine	(Naz et al., 2020)
3.	*Justicia adhatoda, Careya arborea, Calycopteris floribunda, Clerodendrum viscosum, Eupatorium odoratum, Mesua ferea, Azadiracta indica, Plectranthus amboinicus, Centella asiatica, Ocimum sanctum*	Pb*, Cr*, Zn*, Ni*, Cu*, Fe*	Kerala	Presence of HM in growing areas	(Kulal et al., 2020)
4.	*Mimosa pudica, Ocimum sanctum, Allium cepa, Allium sativum, Zingiber officinale, Azadirachta indica, Calotropis procera, Capsicum frutescens, Emblica officinalis, Curcuma longa*	Zn*, Cu*, Fe*	Andhra Pradesh	Habitat contamination	(Srinivas and Rao, 2019)
5.	*Azadirachta indica, Moringa oleifera, Ocimum sanctum*	Zn*	Rajasthan	Habitat contamination	(Rathore and Upadhyay, 2019)
6.	*Vitex negundo*	Cd, Pb, Hg	Chennai	-	(Meena et al., 2019)
7.	*Coriandrum sativum*	Zn, Cu, Ni, Fe	Chhattisgarh	Habitat contamination	(Jena et al., 2019)
8.	*Ficus racemoosa, Zizipus mauritania, Achyranthes aspera, Moringa oleifera, Jasminum officinale, Costusigneus, Madhuca longifolia, Lawsonia intermis, Aegle marmelos*	Zn, Cu*	Karnataka	Chromite mines	(Jagadeesha et al., 2018)
9.	*Blepharismaderaspatensis*	Pb, Cr, Zn, Ni, Cu, Fe*	Tamil Nadu	Habitat contamination	(Vijayalakshmi and Kripa, 2018)
10.	*Coriandum sativum, Trachyspermum, Piper nigrum, Cuminum cyminum*	Cd, Cr, Zn, Cu, Fe	Karnataka	Habitat contamination	(Patil and Morabad, 2017)
11.	*Argemone mexicana, Caesalpinia bonduc, Citus limon, Hibiscus rosa sinensis, Lantana camara, Magnifera indica, Ricinus communis, Piper betel, Punica granatum, Vertex negundo*	Cd*, Cr, Zn*, Cu*, Fe*	North Karnataka	Geographical conditions	(Teerthe and Kerur, 2015)

(*Contd.*)

Table 1: (*Contd.*)

S.no.	*List of medicinal plants*	*Heavy metal with the range reported*	*Region/State*	*Source of contamination*	*References*
12.	*Bacopa monnieri, Dioscorea bulbifera, Hippophae rhamnoides*	Cd, Pb, Hg, As, Cr, Zn, Ni, Cu, Fe	Madhya Pradesh; UttarPradesh: Uttarakhand, and Himachal Pradesh.	-	(Sadhu et al., 2015)
13.	*Aloe vera, Centella asiatica, Calendula officinalis, Cucumis sativus, Camellia sinensis, Clitoriaternatea, Piper betel, Tagetes erecta*	Cu, Cr, Mn, Fe, Ni, As, Pb and Hg	West Bengal	-	(Nema et al., 2014)
14.	*Acacia catechu*	Cd, Pb, Hg, As	Tamil Nadu	-	(Thangavelu et al., 2013)
15.	*Azadirachta indica, Emblica officinalis, Phyllanthus emblica*	Cr, Zn, Cu	Uttar Pradesh	Over usage of the artificial fertilizers, industrial effluents entered into the agricultural lands and other man-made activities.	(Kumar and Ashwani, 2013)
16.	*Acacia nilotica, Bacopa monnieri Commiphora wightii, Ficus religoisa, Glycyrrhiza glabra, Hemisdesmus indicus, Salvadora oleoides, Terminalia bellirica, Terminalia chebula, Withania somnifera,*	Cd, Pb, Cr* Zn, Ni, Fe*	Haryana and Rajasthan	Heavy industrial area	(Kulhari et al., 2013)
17.	*Acalypha indica, Achyranthes aspera, Aristolochina bractelata, Asparagus racemosus, Corallocarpusepigaeus, Citrullus colocynthis, Eclipta alba, Eniocostemma littorale, Glycyrrhiza glabra, Indigofera aspalathoides, Indigofera tinctoria, Lanneacoromandelica, Melothriama deraspatana, Mirabilis jalapa, Mucuna prurita, Oldenlandia umbellate, Plumbago indica, Salacia oblonga,Strychnopotatorum, Strychnosnux-vomica*	Cd*, Pb*, Hg*, As*, Zn, Cu*, Fe*	Tamil Nadu	-	(Rathanavel and Arasu, 2013)

18.	*Meriandra bengalensis, Plectranthusternifolius, Ocimum gratissimum, Acorus calamus, Aloe barbadensis, Vinca rosea, Adhatodavasica, Plantago erosa, Mimosa pudica, Alpinia zerumbet*	Zn*, Cu*, Fe *	North east India	-	(Devi and Sarma, 2013)
19.	*Acalypha indica, Blume, Enicostemma littorale, Nelumbo nucifera, Sphaeranthus indicus, Withaniasomnifera,*	Cd, Pb, Hg, As, Cr*, Zn, Ni, Fe	Tamil Nadu	-	(Moscow and Jothivenkatachalam, 2012)
20.	*Azadirachta indica, Balanites aegyptiaca, Emblica officinalis, Phyllanthus emblica*	Cr, Zn, Cu	Tamil Nadu	Usage of artificial fertilisers, industrial effluent reaches agricultural land areas and other manmade activities.	(Gajalakshmi et al., 2012)
21.	*Ocimumbasilicum, Ocimum minimum, Ocimum sanctum*	Pb*, Hg*, As, Cr*, Zn, Ni, Cu*, Fe*	Chhattisgarh	Fallout of atmospheric pollutants causes dry and wet deposition on plants	(Jena, 2012)
22.	*Adhatodavasica, Aloe barbadensis, Andrographis peniculata, Azadirachta indica, Cassia fistula, Ocimum sanctum, Tribulus terrestris, Withaniasomnifera*	Cd*, Pb, As, Cr*, Zn, Ni, Cu*, Fe*	Haridwar	Plants growing near Khetri Copper Mines	(Maharia et al., 2012)

be rich in plant diversity were found to be contaminated with heavy metals. Several studies have also confirmed the presence of heavy metals in marketed MP raw materials and products (Kumar et al., 2018; Prakash et al., 2014). Cd and Pb were the most common metals detectable in marketed samples collected from various parts of India.

Contamination Reported in Exported Indian Ayurvedic Medicines

Indian traditional remedies are known to contain metals that have healing effects (Singh and Sharma, 2018). Bhasma, a common ayurvedic preparation has lead, mercury, arsenic, cadmium, iron, gold, silver, manganese, copper and zinc added for potency (Punchihewa et al., 2022). Several reports have been published on HM contamination of MP exported from the Indian subcontinent to North America, the Middle East, Western Europe and Australia (Luo et al., 2021). These initially included traditional medicines purchased from India but cases of medicinal products purchased from the UK and US have also shown HM contamination (Dargan et al., 2008). About 21% of ayurvedic medicines prepared by US and Indian companies and dispersed through the internet contained HM contamination of lead, mercury or arsenic (Saper et al., 2008). The presence of these metals in levels beyond the permissible level is one of the main causes that result in the rejection of herbal raw materials with economic repercussions (Bisht et al., 2022).

Sources of Contamination

MPs used in the Indian traditional system of medicine are collected from the wild. Contamination of growing sites can cause the accumulation of heavy metals in raw materials and thereby in finished herbal products (Kulhari et al., 2013). HM spatial variability in atmosphere and soil is affected by anthropogenic and natural sources. These metals are released into the environment from automobiles, electric power plants, industrial activities, metallurgy, and mining as well as due to the use of agricultural runoff of pesticides and fertilizers, etc. (Kalpana et al., 2018).In a study the rise in Cr concentration in MP collected from the Bahadurgah region which is largely an industrial area located at the border of the National Capital Region, New Delhi was attributed to fast urbanisation, higher vehicle density and rapid urbanisation (Kulhari et al., 2013). Maharia et al., (2012)have reported the presence of metals in plants collected from areas around Khetri copper mines and fertile soils in Haridwar, Uttarakhand. The soil in Khetri is known to be metalliferous in nature because of its acidic pH and is known to retain and thereby increase the content of HM. Overuse of fertilisers as well as the release of industrial effluents in agricultural areas have also been implicated as the cause of HM contamination (Gajalakshmi et al., 2012). Wide range of natural habitats have been reported HM contaminations. These include contamination of natural mangroves (Singh et al., 2021). Seasonal changes in the metal content were also noted to be higher in winter and lesser in monsoon and summer. Collection of MP from heavily polluted sites is the main reason for heavy metal contamination found in raw and finished herbal products. MP collected from cultivated sites however show lower levels of HM than expected (Meena et al., 2019) thus bringing forth the most obvious suggestion for resolving the issue which is not to use MP growing near environmentally polluted sites, especially industrial areas (Kulhari et al., 2013). Storage under unhygienic conditions and improper manufacturing practices also contribute to the contamination.

Suggestive Measures to Ensure Quality and Efficacy of MP

As MPs and their products are in such high demand for their medicinal efficacy in pharmaceutical industries, it's critical to assess their effect on health, quality, and efficacy (WHO, 2007). The efficacy of MP-based traditional medications is limited by factors such as lack of drug standardisation, information, and quality control. Following the collection of various varieties of herbal raw drugs from uncultivated, cultivated, or imported sources, they are transported to various market channels, then to various parts of countries, where they are used by various herbal industries, before being prepared for export and retail sale. From the selection of propagation material to customers receiving the final product several steps are required to ensure quality material. These include the selection of the right plant with the correct botanical name, following the right ecological conditions for cultivation and harvesting, right collection practises, controlled drying and storage conditions, and suitable practices of packaging, labelling and documentation (Bisht and Uniyal, 2020). There are around 7800 domestic herbal manufacturing units in India, as well as thousands of practitioners of Indian Systems of Medicine and other associated activities. As a consequence of the lack of transparency in the MP trade, the exact trade statistics are difficult to ascertain.

Ayurvedic medications, homeopathy medicines, and Unani medicine vendors are all subject to different national and state restrictions (Central Council for Research in Ayurvedic Sciences, India, 2018; Patwardhan, 2016). These need to be unified under a national plan. The expanding domestic and international demand for MP has caused rampant unsystematic exploitation leading to loss of the valuable resources. It is imperative to devise innovative cultivation strategies to ensure the continuous supply of the resource. The collection of wild MP and the management of their data is a source of concern. Implementation of quotas for harvesting according to the CITES Appendix II would ensure sustainable collection of MP from the wild supporting livelihood as well as support the fragile ecological systems. Good manufacturing practices (GMP) have been prescribed for Ayurveda, Unani, Siddha, and herbal medicines. Routine inspections at production plants and laboratories and the submission of samples for testing at a government laboratory are mandated. For the protection, maintenance, and fair trading of wild MP, market-based techniques such as FairWild certification exist and others need to be created. In order to accomplish the Sustainable Development Goals 2030, multiple stakeholders must be in agreement on conservation for national policy/strategy at the same time.

Conclusion

The review provides an insight into the magnitude of the issue, its causes and the possible lacuna that needs to be addressed to mitigate the problem. Cd, Pb, Cr, Zn, Ni, Fe, Hg, As were the metals found in the plant samples collected from various contaminated sites in different parts of India. In marketed samples, Cd, Pb, Cr, Zn and Fe were found. Rising water, soil and air pollution are possible sources of contamination of MPs and by-products. Contamination of soil with industrial effluent areas, use of wetlands for disposal of sewage water and use of large-scale fertiliser and pesticides affect the heavy metal accumulation in MP. The introduction of heavy metals in MP can also occur during harvesting, storage, transport or even product processing. The most obvious recommendation would be to grow and gather MP from uncontaminated and controlled sites. Additionally, to fulfill the demand for MP through continuous and transparent trade, it is essential to captivate all stakeholders like farmers, collectors and traders in a comprehensive and inclusive approach for the growth of the MP trade in India.

Acknowledgement

The first author acknowledges the Research Fellowship granted by the University Grants Commission, India.

Conflict of interest

The authors declare no conflict of interest.

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Asian Journal of Water, Environment and Pollution

Volume 19 Number 6 **November, 2022**

Contents