REVIEW

Heavy Metal Pollution in Sri Lanka with Special Reference to Agriculture: A Review of Current Research Evidences

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Abstract
Heavy metals are ubiquitous and chemically stable elements, which can be supposed to be present in all parts of the biotic and abiotic environments. Anthropogenic activities and some natural environmental events appear to be causative factors which create heavy metal pollution in the environment. It has been well established that excess exposure to heavy metals produces adverse health effects on human beings. In this review, current scientific data on heavy metals were assessed with regard to geo-environmental and health aspects. Reported levels of heavy metals such as cadmium (Cd), arsenic (As), lead (Pb), nickel (Ni), zinc (Zn), copper (Cu), mercury (Hg), manganese (Mn) and chromium (Cr) in the Sri Lankan environment are discussed in this article. Scientific evidence reveals that the Sri Lankan soil and water bodies are within the safe level for daily activities of people and agricultural practices with a few exceptions. Some agricultural practices act as the major source of heavy metal pollution in Sri Lanka. In order to fully uncover the heavy metal pollution levels in the soil and water in the whole country, further studies are required at the national level.
Key words: Heavy Metals, Pollution, Sri Lanka, Soil, Water.

Introduction

Heavy metals are natural elements found in many environments throughout the world. Some of these metals are detrimental to plants, animals and humans due to their ability to bio-accumulate in the food chain. Heavy metals enter into the environment from natural[1] and anthropogenic sources[2,3] and the quantity enters the ecosystem from the latter sources is considerably higher[4].

Activities such as agricultural practices, industrial emissions, mining and smelting of metal ores etc. have contributed to elevated levels of heavy metals in the environment[5]. Although heavy metals are naturally available in very low concentrations in the environment, they are considered as pollutants since they cause acute and chronic toxicities and because of their wide spreading nature[6]. There are large numbers of metals and metalloids included under the category of heavy metals. However, in this review the following elements are considered due to their high availability in ecosystems: Cd, As, Pb, Ni, Zn, Cu and Hg.

Some agricultural practices are commonly considered as the major sources of adding heavy metals to the environment. Cultivation practices, such as fertilization, irrigation, pesticide application and organic waste disposal are assumed as the routes of entry of heavy metals in agricultural soils[7]. It has been reported that agriculture is one of the fundamental sources of heavy metal pollution in coastal areas of Sri Lanka[8].

The contamination of agricultural soil by heavy metals has become a serious environmental problem due to their adverse environmental effects. Several studies have shown that there are adverse effectsdue toexcess exposure to heavy metals, especially Cd[9,10], Cu[11], Cr[12] and Pb[13] on growth and developmentin many plant species.

Heavy metals cause health issues when they enter the human body *via* food chain.The consumption of contaminated foods has been taken into account as the primary pathway for human exposure to potentially toxic heavy metals[14]. Bioaccumulation of heavy metals has received an increased attention in recent years owing to their probable health impacts. The accumulation of toxic heavy metals in the human body has been reported to cause renal dysfunctions[15], cancers[16,17], defective bone mineralization[18], problems in the digestive system and anemia[19]. Previous studies have shown that there are potential nephrotoxic effects of Hg, Cr, U, Pb and Cd[15]. As an example, cadmium is one of the well-established nephrotoxicants, both with acute and chronic exposures[20]. Further, chronic As poisoning among people living in many areas of the world has been reported as it may cause different life-threatening diseases[21]. In some areas of Taiwan, increased exposure to As caused a significant increase of renal diseases[22].

Therefore, an understanding of the present status of heavy metals in the ecosystem is vital to critically assess the heavy metal contamination levels of the environment as it leads to major environmental and health concerns. This information would be important to carry out preventive and mitigating actions to minimize human exposure and the resulting threat to the natural ecosystem. This review is focused on the evaluation of status of the major heavy metals in diverse environments of Sri Lanka giving priority to Cd and As due to their importance in human health and environmental toxicity.

Methodology

A systematic literature review was conducted as described by Khan et al.[23] to identify relevant publications. The following keywords were used: air pollution, Chronic Kidney Disease (CKD), Chronic Kidney Disease of unknown etiology (CKDu), environmental pollution, heavy metals, North Central Province Sri Lanka, soil pollution, Sri Lanka and water pollution. Published papers, review articles, chapters in books, reports and abstracts were reviewed to prepare this paper. References from papers and review articles were used for further search of literature.

Agricultural Sources of Heavy Metals in the Environment

Heavy metals occur naturally in the soil environment of the pedogenic processes of weathering of bed rock or parental materials. Due to the acceleration of the natural process of releasing metals by man-made activities, most rural and urban environments have the potential to accumulate one or several heavy metals compared to the naturally available levels. It is postulated that the anthropogenic emission of several heavy metals to the atmosphere is one to three times higher than the natural emission[24]. Furthermore, heavy metals in the soil from anthropogenic sources are more mobile than natural emission, hence they are bioavailable than pedogenic ones[25,26]. Reported status of heavy metals of following anthropogenic sources that are used in Sri Lanka in the form of fertilizers, liming materials, manures and pesticides is discussed here-in- under.

Large quantities of fertilizers are regularly added to soils in modern intensive farming systems to provide N, P and K to enhance crop growth and yield. Fertilizers used to supply these elements contain some heavy metals as impurities. Contamination of phosphate fertilizers by toxic metals during the manufacturing process is well-established. Lu *et al*[27] reported that the phosphate fertilizers are major sources of trace metals among all inorganic fertilizers. Significant levels of Cd, Hg, Pb, U and Cr were reported in final products of phosphate fertilizers that are ready for marketing[28]. This shows that continued

application of inorganic fertilizers may significantly increase the heavy metal content in the soil[29].
Fertilizer sources from different farming systems in Sri Lanka have been reported containing certain amounts of some heavy metals. Though there is lack of information available to see heavy metals in urea and other fertilizers, the study of Chandrajith *et al*[30] has shown the contamination of urea and NPK fertilizers with heavy metals. Among the fertilizers, triple super phosphate (TSP) contained significantly higher amounts of Cd, Pb, Ni, Cr and Al compared tothose present in urea and NPK fertilizers (Table 1). According to the permissible levels set by the Sri Lanka Standards Institution (SLSI), the maximum permissible level of Cd in compost that is applicable for agricultural fields is 10 mg/kg. Chandrajith *et al*[30]showed that the TSP collected from Medirigiriya and some parts of Giradurukotte had higher levels of Cd than other fertilizers. Table 1 shows the reported toxic trace element contents in different fertilizer sources used in different regions of the country as stated by Chandrajith *et al.*[30].

Heavy metal concentrations in some inorganic phosphate fertilizers, manures and liming materials were studied by Premarathna et al[31] and the reported levels of heavy metals in different fertilizer sources are present in Table 2. The levels of Cu, Ni, Pb and Zn were below the levels set by the SLSI except for Cd in some phosphate fertilizers, and Cd levels were higher in Imported Rock Phosphate (IRP) andTSP (Table 2). This study shows that the TSP contained the highest amount of Cd and Sri Lankan apatite of Eppawala rock phosphate had a relatively low amount of Cd.

According to the research findings stated above, though some fertilizer sources used in Sri Lanka do not contain higher levels of heavy metals compared to the SLSI standards, there is a risk of adding heavy metals into the soil environment with the use of contaminated fertilizer sources. The frequent application of fertilizers, manures and liming materials in large quantities for a long time period may contribute to an increase in the levels of heavy metals in the farming areas. Furthermore, there are sufficient evidences to prove that the addition of excess Cd to Sri Lankan soil with the use of contaminated phosphate fertilizers[30,31]. Though the major Cd related environmental problems have not been reported yet in Sri Lanka, there exists a risk of emergence of such problems in the near future, if mitigation actions are not taken to reduce the human exposure to Cd through the use of contaminated phosphate fertilizers. Moreover, according to the facts described in above sections, application of contaminated fertilizer sources to crop fields can be a route of entry of heavy metals to agricultural soils in Sri Lanka. Therefore, the Government of Sri Lanka (GOSL) and relevant authorities are required to take actions to reduce the importation and use of such contaminated fertilizers.

Several extensively used pesticides in the agricultural sector in the past decades contained a significant amount of heavy metals. In the UK, about 10% of the insecticides and fungicides used contained Cu, Hg, Mn, Pb and Zn[32]. The well-known Cu containing fungicide used was Bordeaux mixture. The use of As-based compounds for pest prevention in agriculture prevailed for over hundreds of years until the mid-1900s[33]. Davenport and Peryea[34] reported that significant increase of leached As was from the soils contaminated with lead arsenate pesticide residues. Some modern use of As based pesticides still exists. Chromated Copper Arsenate is used in the United States as a wood preservative in nonresidential applications. Compared to theamount of fertilizers applied to the crop fields, the amount of pesticides applied is lower, because pesticide application is dependent upon the crop and the type of pest, disease or weed. Butcontinuous application canstill contribute to increase in the total heavy metal concentration in soils.

A group of academics and medical officers recently claimed about elevated levels of As in some pesticides in Sri Lanka Wijesekara and Marambe[35] found higher As levels in some pesticides samples collected from sales outlets in Padaviya, Siripura, Girandurukotte and Dehiattakandiya in Sri Lanka and three pesticides namely Glyphosate, Carbofuran and Thiocyclam contained the detectable levels (i.e. > 50 µg/L) of As (Table 3).

Based on the harmful effects, GOSL banned the importation, use and sale of five pesticides namely Glyphosate, Propanil, Carbaryl, Cholopyrifos and Carbofuran. Further, the use of the above pesticides is prohibitedin the districts of Anuradhapura, Polonnaruwa, and Kurunegala, and also within the Divisional Secretariat Divisions of Mahiyanganaya, Rideemaliyadda and Kandaketiya in the Badulla District.

Table 1. Heavy metal content (mg/kg) in different fertilizers in different regions of Sri Lanka[30].

		Amount of Heavy Metals (mg/kg)				
Collected Location	Fertilizer Type	Cd	Pb	Ni	Cr	Al
Anuradhapura	Urea	0.40	3.80	1.40	3.90	37.00
	NPK	0.40	3.80	1.40	3.90	203.00
	TSP	3.60	50.70	35.20	52.90	9,949.00
Medawachchiya	Urea	0.40	3.80	1.40	3.90	32.00
	NPK	0.40	3.70	1.40	3.90	262.00
	TSP	4.00	79.20	27.10	43.60	9,405.00
Medirigiriya	Urea	0.40	3.70	1.40	210.30	25.00
	NPK	0.40	3.80	1.40	23.70	135.00
	TSP	46.10	41.10	22.30	59.50	8,563.00
Girandurukotte 1	Urea	0.40	6.00	1.40	19.60	54.00
	NPK	0.40	3.80	1.40	22.80	143.00
	TSP	39.80	58.20	24.20	65.90	9,016.00
Girandurukotte 2	Urea	*nd*	4.00	1.60	*nd*	27.00
	NPK	0.50	2.60	1.30	2.60	77.00
	TSP	2.30	67.20	10.60	19.20	5,177.00
Kandy	Urea	0.40	3.90	1.40	21	52.00
	NPK	0.60	3.80	1.40	22.10	140.00
	TSP	4.30	80.20	27.30	62.10	10,113.00

nd- not detected

Soil Availability and Mobility of Heavy Metals

The most common heavy metals likely to cause some reported health problems in Sri Lanka are Cd[36] and As[37]. These metals are also important for agriculture and food production since they are capable of reducing the growth and the production of crops due to the risk of bio-magnification through the food chain. The knowledge of basic soil chemistry of such heavy metals is required for understanding their mobility, bioavailability and for potential remediation processes. Once in the soil, heavy metals are adsorbed by fast reactions and subsequently by slow reactions. Then the absorbed heavy metals are redistributed in different chemical forms with varying bioavailability, mobility and toxicity[38]. It has been reported that the bioavailability of heavy metals is affected by pH, organic matters, cation exchange capacity of the soil, other cations in the soil solution, oxidation and reduction reactions, ability to form soluble complexes and the impact of soil microflora[39].

Table 2. Trace Metals in Fertilizers and Manures[31].

Fertilizer/ Manure Source	Amount of Heavy Metals (mg/kg) Cd	Cu	Ni	Pb	Zn
Cattle manure	0.43	8.23	4.70	1.10	57.50
Poultry manure	0.97	23.90	6.87	3.20	220.10
IRP	12.18	47.85	18.30	13.50	63.70
Lime	6.53	0.87	15.65	12.85	7.05
ERP	1.92	35.50	26.60	13	61.90
Apatite	1.32	32.35	14.20	12.20	58.60
Dolamite	9.06	0.10	9.85	16.90	20.20
TSP	23.50	9.50	20.40	5.15	130
Heavy metal levels permitted in compost by SLSI	10	400	N/A	250	1000

IRP: Imported rock phosphate; ERP: Eppawala Rock phosphate; SLSI: Sri Lankan Institute of Standards; N/A: Not available

Cadmium: Cadmium is one of the toxic heavy metals of which biological function is yetunknown. In nature, Cd is released as a result of rock mineralization process and exists as a divalent cation. The Cd exhibits chemical similarities to Zn, an essential micronutrient for plants and animals. Thus, the substitution of Zn by Cd causes the malfunctioning of Zn absorption and metabolic processes[40]. Cadmium is highly mobile under acidic conditions[41]. Therefore, mobility of Cd in upcountry Wet Zone soils becomes high where pH is around 4.5. Soil in North Central Province (NCP), of Sri Lanka is considered to be neutral to alkaline, which reduces the mobility of Cd in NCP soil compared to the upcountry Wet Zone soils. Ground water sources from NCP contain high levels of calcium[42], which can compete for adsorption sites. This results in releasing Cd ions to the soil solution and subsequent increase in Cd ion concentration in water.

Arsenic: Arsenic is a metalloid ion that occurs in a wide range of minerals mainly as As_2O_3 and can be recovered from processing of ores containing Cu, Pb, Zn, Ag and Au[43]. Arsenic exhibits a comparatively complex nature of chemistry and can be available in several (-III, 0, III, V) oxidation status[44]. In aerobic conditions, As (V) is dominant in the form of arsenate (AsO_4^{3-}) in different protonation forms as, H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$, and AsO_4^{3-} These anionic forms of As can behave as chelates and precipitate when metal ions are present[45]. Arsenic (III) dominates under reducing conditions and exists in several protonated forms of arsenite (AsO_3^{3-}) as H_3AsO_3, $H_2AsO_3^-$ and $HAsO_3^{2-}$. Arsenite can be adsorbed into metal sulfides and exhibit high affinity for other sulfur compounds[43]. Many As compounds are strongly adsorbed into soils and thus transported only for short distances in ground water and surface water. But As mobility increases with increasing soil pH[44].

Status of Heavy Metals in Sri Lankan Soil

Soil and reservoir sediments are known as the most suitable indicators of heavy metal contaminations as these substances can easily catch heavy metals due to the presence of high amount of negatively charged clay particles and organic matters[46]. The concentrations of heavy metals in soils of different regions of the country, as reported in the available literature, are described in subsequent sections.

Table 3. Amount of As in pesticides used in Sri Lanka[35]

Generic Name of the Pesticide	Amount of Arsenic (μg/kg)
Bispyribac-Sodium 10 SC	*nd*
Glyphosate (acid equivalent) 360 g/L EC	334
Ethofenprox 100g/L EC	*nd*
Imidacloprid 70% WG	*nd*
Profenofos 500 g/L EC	*nd*
Carbosulfan 200 g/L SC	*nd*
MCPA 600 g/L SL	*nd*
Fenoxaprop-p-ethyl 69 g/L	*nd*
Carbofuran 3% G	166
Chloprifos 400 g/L EC	*nd*
Fenoxaprop-p ethyl 69 g/L OD	*nd*
Chlorpyrifos 400 g/L EC	*nd*
Ptretilachlor+Pyribenzoxim 300+20 g/L EC	*nd*
Quinalphos 250 g/L EC	*nd*
Fenoxaprop-P-ethyl+Ethoxysulfuron 69+20 g/L OD	*nd*
MCPA 600 g/L SL	*nd*
Chlopyrifos 400 g/L EC	*nd*
Fenobucarb 500 g/L EC	*nd*
Mancozeb 80% (w/w) WP	*nd*
Quinalphos 250 g/L EC	*nd*
Tebuconazole 250 g/L EW	*nd*
Diazinine 500 g/L EC	*nd*
Glyphosate (acid equivalent) 360 g/L SL	370
Thiocyclam 50% SP	156

nd- not detected, Limit of quantification = 50 μg/L[35]

During the recent past, Sri Lankan researchers have focused more on assessing the level of heavy metal contaminations in CKDu prevalent areas of the country in order to understand an association between heavy metals and the disease. Data from one such study revealed that the Pb content is higher and Mn, Cr, Ni and Zn contents are lower in dry zone soils compared to soils from the wet zone[47].

The use of contaminated agrochemicals is one of the most controversial issues of the environment in the past few years in Sri Lanka. Therefore, several studies had been initiated to explore this issue. In terms of this context, one such interesting study showed that surface soil samples including paddy soils from Padaviya, contained relatively higher levels of total arsenic than in the deep layers of the soil profile[48]. Another study reported that the average concentrations of As, Mn, Pb, Cu and Ni of the agricultural soil in Madirigiriya, Thalawa and Padaviya were slightly higher than that of the non-agricultural soil in the same geographic area (Table 4)[49]. However, the recommended As content in earth's upper continential crust (UCC) is 4.8 mg/kg[50]. It was found that around 60 samples that were used for the study had As level below 5mg/kg, while around 10 samples reflected relatively higher values with respect to the UCC value. Furthermore, the concentration of As in the soils of all the above areas was below the guideline value for inorganic arsenic in soil in the residential areas (i.e. 32 mg/kg), which was set by the Environment Agency of the United Kingdom in 2009[51]. Although the reported As values do not exceed the recommended levels set by different authorities, there is a possibility of the soil getting contaminated with As due to agricultural practices in the future. This is also possible with other reported heavy metals too.

The upper limit of the geochemical baseline concentration for Cd in Medawachchiya - Ranorawa - Elayapattuwa - Hurathgama - Nawagaththegama soil map unit in the Dry Zone,of Sri Lanka was found to be 1.39 mg/kg[52]. This value is below the recommended upper limit of Cd for sewage sludge amended soils (i.e. 3 mg/kg), as per European Union[53]. Results of one of the recent studies also showed that soil Cd, Cu, Ni, Pb and Zn levels in the same soil catena were within the safe limits[54] as far as human health is concerned. Therefore, this soil catena can be considered safe to grow crops for human consumption with respect to heavy metal pollution. However, Rosemary *et al*[54] indicated the influence of agricultural practices to build up some heavy metals in cultivated soils (Table 5). The average values of Cd, Cu and Ni in paddy and vegetable growing lands are comparatively higher than those present in uncultivated lands (Table 5).

Table 4. Average concentration of As, Mn, Pb, Cu and Ni in agricultural and non-agricultural soils in Madigiriya, Thalawa and Padaviya in Sri Lanka (values represent the calculated index values ± SD)[49]

Element	Medirigiriya		Talawa		Padaviya	
	Non-agricultural soil	Agricultural soil	Non-agricultural soil	Agricultural soil	Non-agricultural soil	Agricultural soil
As	2.00±1.00	3.00±2.00	3.00±1.00	5.00±2.00	2.00±1.00	5.00±7.00
Mn	0.11±0.05	0.16±0.04	0.10±0.03	0.15±0.08	0.15±0.05	0.17±0.10
Pb	15.00±3.00	21.00±10.00	19.00±3.00	28.00±11.00	13.00±4.00	32.00±43.00
Cu	19.00±10.0	25.00±10.00	21.00±6.00	23.00±6.00	26.00±12.0	57.00±34.00
Ni	24.00±13.0	40.00±16.00	26.00±5.00	30.00±7.00	37.00±15.0	54.00±27.00

Elevated levels of heavy metals in some parts of intensive vegetable growing areas of up country and low country wet zone regions of the country have been reported[31]. Soils from Sedawatta area in the Colombo district, belonging to low country wet zone have the highest concentration of Cd, Cu, Ni, Pb and Zn as compared to other areas in the low country and up country wet zone regions[31] (Table 6). Furthermore, in a field in Haputale, which is in the upcountry wet zone region had the highest soil Cd concentration (3.86 mg/kg)[31]. This value exceeded the European Community set standards in 1986 for the upper limit of Cd allowed in agricultural soils treated with sewage sludge (i.e. 3 mg/kg). However, heavy metal contents in soils in the upcountry intensive vegetable grown areas are greater than that of non-cultivated soils (Table 6).

Table 5. Average amount of heavy metals in different land uses in Medawachchiya – Ranorawa – Elayapattuwa – Hurathgama – Nawagaththegama soil catena (values are mean ± SD)[54]

Element	Amount of Heavy Metals in Different Land Uses (mg/kg)		
	Paddy cultivation	Vegetable cultivation	Uncultivated
Cd	0.35±0.16	0.28±0.17	0.26±0.18
Cu	2.43±0.85	2.97±1.39	2.36±1.91
Ni	4.95±3.27	7.22±4.32	4.69±2.73

In most of the wetlands, especially in urban areas receive considerable loads of pollutants including heavy metals. The concentrations of Pb, Cd, Cr and Cu existing in Kolonnawa wetland have also further exceeded threshold limits for aquatic organisms[55].

Status of Heavy Metals in Reservoir Sediments

Reservoir sediments would be very good source for estimating heavy metals received by the catchment, since most of runoff of agricultural inputs ends up in the reservoir. The mean Cd concentration of sediments of Kumbichchankulama, Alankulama and Thuruwila reservoirs in Anuradhapura district was 2.42, 2.45 and 2.18 mg/kg,respectively[36]. Another study has reported that the mean Cd content in reservoir sediments of the Dry Zone, Sri Lanka is 3.243 mg/kg[46]. The latter is a higher concentration of Cd than the previous study. In addition, a study which was conducted in the Greater Colombo Canal System revealed that Cr, Mn and Ni were not found in polluted levels in the sediments[56]

Status of Heavy Metals in Water

During the recent past it was assumed in the country that water sources in the Dry Zone of the country are polluted with some toxic heavy metals. Thus following paragraphs review the existing status of such heavy metals in the Sri Lankan water sources.

Table 6. Total heavy metal concentrations in intensive vegetable growing areas of up country and low country wet zone soils (mg/kg).[31]

Region	District	Sub area	Amount of Heavy Metal (mg/kg) Cd	Cu	Ni	Pb	Zn
Low country	Colombo	Sedawatta	0.61-3.28	49-111	19-28	39-113	259-420
		Welewatta	0.46-1.37	33-39	20-27	34-66	171-302
		Kotuvilla	0.98-1.31	24-48	12-16	20-56	287-353
	Kaluthara	Kahathuduwa	0.49-1.55	17-34	7-26	17-33	18-376
		Bandaragama	0.53-0.89	7-14	4-13	15-15	49-121
		Mean value	1.18	51	20	54	318
		Control soil	0.26	13	5	49	62
Up country	Nuwara-Eliya	Sitha-Eliya	0.51-0.88	80-95	7-15	56-311	127-359
		Kandapola	0.39-1.96	34-41	7-43	27-97	178-193
		Haputale	0.51-3.86	34-97	3-16	26-242	121-486
		Bogahakubura	1.30-1.42	58-106	6-28	45-75	56-194
		Rahangala	1.22-1.29	114-139	8-67	97-116	141-342
		Mean value	1.21	72	23	88	312
		Control soil	0.51	14	0.83	40	104

There were several studies conducted during 1985 – 1987 to determine the extent of heavy metal contamination in surface water from the Mahaweli and Kelani rivers, Kandy lake and Mid-Canal in Kandy. These studies revealed that V, Zn and Cu were higher in Mahaweli river,[57] and the highest concentrations of Pb (150 ppb) and Cd (80 ppb) were in the surface water collected from Kandy lake[58].

The level of dissolved Cd in water in Kumbichchankulama, Alankulama, Thuruwila, Karapikkada and Ulukkulama reservoirs in Sri Lanka was in the range of 0.03–0.06 mg/L[36]. This value exceeded the maximum allowed contaminant level of 0.005 mg/L set by United States Environment Protection Agency (USEPA) for drinking water. However, these findings have been challenged by subsequent studies. The findings of one such study have shown that Cd concentration in water from the same irrigation reservoirs (0.3 µg/L) was below the World Health Organization (WHO) set standards (i.e. 3 µg/L) for drinking water[46]. In the same study, the authors have reported that wells in the CKDu prevalent areas in the country are not contaminated with toxic metals,and the concentration of Cd in reservoir water samples from Ambagasweva and Medirigiriya was below the WHO recommended level for drinking water. Moreover, Bandara *et al.*[36]reported that no detectable levels of dissolved As and Cr in the above mentioned reservoirs, while Jayawardana *et al.*[49]showed that ground water samples collected from Wet, Dry and Intermediate zones had less than 10 ppb, which is below the WHO recommended level for As.

According to the research findings discussed in this article, there are some places in the country with higher levels of different heavy metals compared to the set standards by different authorities. When heavy metals are available in the environment in relatively high concentrations, there is a possibility for people to be exposed to such heavy metals due to diverse human activities. In such situations, special attention is needed to mitigate the rise of heavy metal levels, which otherwise lead to probable environmental and human health consequences.

Figure 1 shows a conceptual model to see the flow of heavy metal to human through the agricultural practices. There are numerous approaches employed by scientists to minimize the reaching of heavy metals in the food chain by reducing its uptake by plantsby promoting immobilization and remediation of heavy metals in contaminated sites. The application of both chemical and organic immobilization agents such as clay, cement, zeolites, minerals, phosphates, organic composts and microbes to contaminate soils is often used to accelerate the attenuation of metal mobility in soil[59,60]. It has been reported that Zeolite can effectively suppress Cd uptake by rice and wheat compared to calcium carbonate and magnesium oxide[61]. Furthermore, addition of compost prepared using chicken and pig manure to soil grown cherry-red radish has decreased the phytoavailability of Cd[62]. The phytoremediation, reducing heavy metals in polluted sites by using metal-accumulating plants is still in its experimental stages, and has not been used in full-scale application[43]. This technique is widely tested in many countries in the world with different plant species as a measure to reclaim heavy metal contaminated soils., However, phytoremediation related technologies such as, phytoextraction (phytoaccumulation), phytostabilization and phytofiltration techniques are frequently used. However, in Sri Lanka, such technologies are still not industrialized.

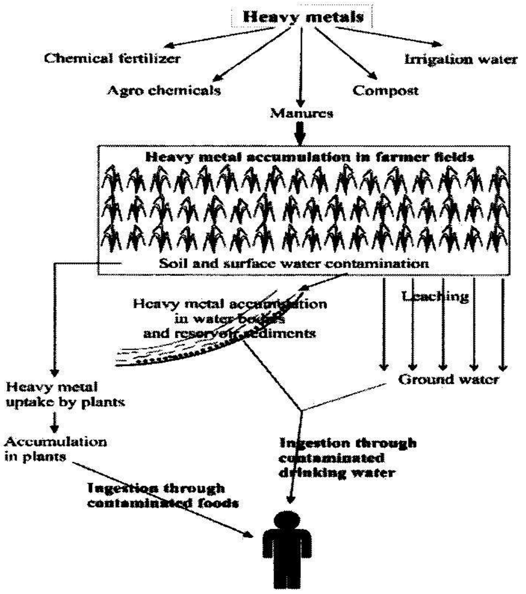

Figure 1: Conceptual model showing metal flow to human through agricultural systems

Future Directions

Although heavy metals are known as hazardous environmental pollutants, the management of heavy metal pollution in the environment seems unsatisfactory. Even the research programs aligned towards monitoring and control of heavy metal pollution seems to be currently at the infant stage. To address environmental issues connected with heavy metals, multidisciplinary research is very much needed. Currently, Sri Lanka lacks scientific data to fully recognize the status of potentially toxic (i.e. for both environment and human) heavy metals in soil, air, drinking and irrigation water sources, different sources of organic and inorganic fertilizers and pesticides and food systems. There is also a great deficiency of information on heavy metal related health issues, occupational and community exposures to heavy metals, sources of heavy metals, fate of heavy metals in human and plant bodies, plant uptake studies, remediation studies of metal contaminated lands and desirable regulations, guidelines and standards for commodities.

Sri Lanka will now need to consider more on the prevention of using heavy metal contaminated agricultural inputs and different industrial commodities in our daily activities. This urgently requires data on heavy metals and their levels in soil, drinking water sources, residential areas, food items including grains, vegetables and fruits and pathways to food chain, and human exposure and guideline values to monitor current levels.

Furthermore, there is a special concern on Cd and As within the country, since these two heavy metals are known to cause health issues in human in many parts of the world. Increased contamination of Cd and As in the agricultural ecosystem due to extensive use of contaminated agrochemicals would lead to health issues in the country. This requires implementation of frequent monitoring of sources and rate of contamination followed by strict preventive measures.

Conclusion

Heavy metals are ubiquitous in the environment. Some degree of exposure to heavy metals by people is practically inevitable. There is adequate literature available globally on human health issues linked with heavy metals and possible concerns about the environment. The upto date knowledge is disclosed in this review, with a few exceptions. Sri Lankan soil and water bodies are still within safe levels to continue with agriculture and different daily activities. However, soils and reservoirs which are located in and close to the agricultural fields seem to be the reserve of heavy metals. Though there are results of several studies available on the presence of heavy metals within the country, these levels do not confirm health issues coupled with such levels. Further, there is a lack of information of heavy metal contamination and of country specific guideline values for different sources of heavy metals that are intensively used for agriculture. This warrants the need for well-planned studies to explore the uncovered areas of the country in terms of heavy metals and the potential pollution.

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