Heavy Metal Pollution of Agricultural Soils and Vegetables of Ngazun Township, Mandalay Division

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Abstract

The aim of this research was to assess heavy metals (Cu, Zn, Pb, Cd) in soils as well as in vegetable from Ngazun Township, Mandalay Division. Fertilizers and pesticides are used for the growth of plants and vegetables in agricultural fields. The use of fertilizers and pesticides has been causing environmental pollution and accumulation of heavy metal in soils. Health risks occur due to the consumption of vegetables in agricultural fields.

Key words: Heavy metals; Soils; Vegetables; Accumulation.

Introduction

Soil is not only the key nutrient-bearing environment for plant life but also a supplier of many pollutants to plants because plants can uptake toxic substances through their roots from soils. Heavy metals are extremely persistent in the environment; they are non-biodegradable and non-thermo degradable and thus readily accumulate to toxic levels. Heavy metals can accumulate in the soil at toxic levels due to the long term application of wastewater. Monitoring of the contamination of soil with heavy metals is of interest due to their influence on ground water and surface water and also on plants, animals and humans. Increase in human population as well as proportionate increase in the requirement of food is one of the challenges in the world. The existing farming practice explores high yielding varieties and intensive cropping pattern that requires higher use of external inputs such as irrigation, pesticides use and so on for more yields.

Sources of Heavy Metals in Contaminated Soils

Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg-kg^{-1}) and rarely toxic. The heavy metals essentially become contaminants in the soil environments because (i) their rates of generation via man-made cycles are more rapid relative to natural ones, (ii) they become transferred from mines to random environmental locations where higher potentials of direct exposure occur, (iii) the concentrations of the metals in discarded products are relatively high compared to those in the receiving environment, and (iv) the chemical form (species) in which a metal is found in the receiving environmental system may render it more bioavailable. A simple mass balance of the heavy metals in the soil can be expressed as follows:

$$M_{total} = (M_p + M_a + M_f + M_{ag} + M_{ow} + M_{ip}) - (M_{cr} + M_l) \qquad (1)$$

where, M = the heavy metal, p = parent material, a = the atmosphere deposition, f = the fertilizer sources, ag = the agrochemical sources, ow = the organic waste sources, ip = other inorganic pollutants, cr = crop removal, l = the losses by leaching, volatilization

Basic Soil Chemistry and Potential Risks of Heavy Metals

The most common heavy metals found at contaminated sites, in order of abundance are Pb, Cr, As, Zn, Cd, Cu, and Hg. Those metals are important since they are capable of decreasing crop production due to the risk of bioaccumulation and bio-magnification in the food chain. There’s also the risk of superficial and groundwater contamination. Once in the soil, heavy metals are adsorbed by initial fast reactions (minutes, hours), followed by slow adsorption

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reactions (days, years) and are, therefore, redistributed into different chemical forms with varying bioavailability, mobility, and toxicity.

Lead

Lead is not an essential element. It is well known to be toxic and its effects have been more extensively reviewed than the effects of other trace metals. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys. Inhalation and ingestion are the two routes of exposure, and the effects from both are the same. Lead accumulates in the body organs (i.e., the brain), which may lead to poisoning or even death. The gastrointestinal tract, kidneys, and central nervous system are also affected by the presence of lead. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration, with children under the age of six being at a more substantial risk. Adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead. Exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing young and infants being more sensitive than adults. Lead poisoning, which is so severe as to cause evident illness, is now very rare. Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains.

Chromium

Most of chromium released into natural waters is particle associated, however, and is ultimately deposited into the sediment. Chromium is associated with allergic dermatitis in humans. Whereas chromium (III) is an essential element, chromium (VI) compounds are known to be mutagenic and carcinogenic. Breathing high levels of chromium (VI) may cause asthma and shortness of breath. Long term exposure may cause damage to the liver and kidneys.

Arsenic

Many Arsenic compounds are absorbed strongly into soils and are therefore transported only over short distances in groundwater and surface water. Arsenic is associated with skin damage, increased risk of cancer, and problems with circulatory system.

Zinc

Many foodstuffs contain certain concentrations of Zn. Drinking water also contains certain amounts of Zn, which may be higher when it is stored in metal tanks. Industrial sources or toxic waste sites may cause the concentrations of Zn in drinking water to reach levels that can cause health problems. Excessive intake of Zinc and Copper may cause non-carcinogenic effects on human health, even though they are essential to human life. Cu surplus had been associated with liver damage while Zn may cause impairment of growth and reproduction. Zinc shortages can cause birth defects.

Copper

Copper is the third most used metal in the world. Copper is an essential micronutrient required in the growth of both plants and animals. In humans, it helps in the production of blood haemoglobin. In plants, Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in high doses it can cause anaemia, liver and kidney damage, and stomach and intestinal irritation. Copper normally occurs in drinking water from Cu pipes, as well as from additives designed to control algal growth.

Experimental Setup

Study Area

Ngazun Township is located in the west part of Mandalay, Myanmar. The township is bounded by Tada-U Township in the east and Myotha in the south. Mandalay is located in the central dry zone of Myanmar. The area is characterized by the central zone tropical region.

Sample Collection and Sample Preparation

To analyze, six soil samples were collected from agricultural fields and three vegetable samples were collected in agricultural fields. The three soil samples are topsoil (0-15cm) and the rest are at a depth of 60cm from agriculture field of Ngazun Township area. Six soil samples and three vegetable samples were dried at room temperature for one week. The dry samples were pounded in hand blender to make them into a fine powder and sieved in 1mm mesh. These samples were placed in plastic bag and were weighed by using a high sensitive digital weighing balance. Figure (1), (2) and (3) were shown the samples preparation.

Figure (1.a) The Rice Sample and its Powder

Figure (1.b) The Soil Sample and its Powder (in Rice field)

Figure (2.a) The Pigeon-Pea Sample and its Powder

Figure (2.b) The Soil Sample and its Powder (in Pigeon-Pea field)

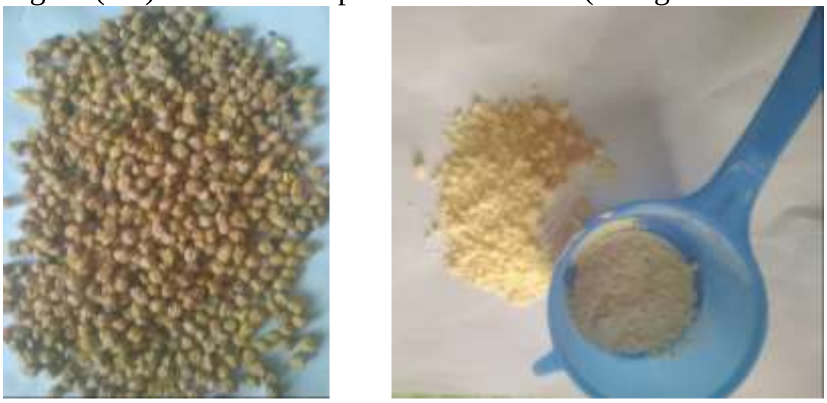

Figure (3.a) The Chick-Pea Sample and its Powder

Figure (3.b) The Soil Sample and its Powder (in Chick-Pea field)

Experimental Setup

Soil samples were analyzed by using energy dispersive X-ray fluorescence system. All of the pellet samples were analyzed 600 sec for four secondary targets with Rigaku system and measurement atmosphere is helium purge. It is used 50 kV bias voltage and tube current is automatically adjusted by hardware. The analyzed range is 0-50 keV. The electron beams are incident on the palladium (Pd) anode target of X-ray tube. The X-ray from the Pd target excites the atoms of the sample to emit radiation. Secondary targets used in this spectrometer are RX9, Copper (Cu), molybdenum (Mo) and Aluminum (Al). The X-ray spectrum is analyzed with the help of computer to obtain the concentration of each element in the sample. This experiment was done in University Research Centre, Taunggyi University.

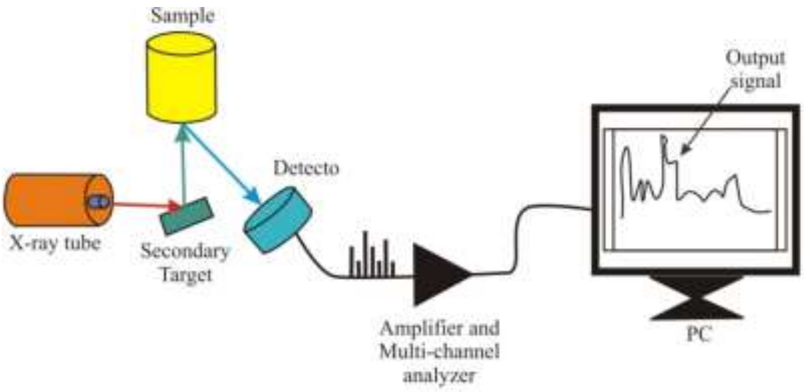

Figure (4) The schematic instrumental components of EDXRF analyzer

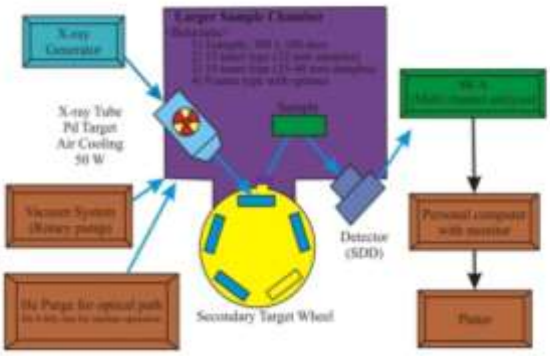

Figure (5) The X- Ray Detection System

Results and Discussion

All samples were analyzed by using EDXRF; it can measure virtually every element from Mg to U. 30 elements are found in each sample in the analyzed results. These elements contain 16 heavy elements and 14 light elements. Average concentrations of analyzed results in $mgkg^{-1}$ from different samples of the Ngazun Township area are shown in Table (1), (2) and (3). The minimum concentration ranges were as follows; Co($37mgkg^{-1}$), Pb($13mgkg^{-1}$), Cr($62mgkg^{-1}$), Cu($9mgkg^{-1}$) and As($3mgkg^{-1}$) respectively. The concentrations were used to calculate Geo-accumulation Index (I_{geo}). The results presented show that the average concentrations of heavy metals in soils as well as in vegetable from the Ngazun Township area varied and decreased in the order Co>Pb>Cr>Cu>As. Compared with recommended maximum allowable limits for Taiwan and other countries are shown in Table (4). Our calculated results were found to be the lowest in the present area.

Sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), chlorine (Cl) and phosphorus (P) are essential elements for human life. Because they provide essential ions in body fluids and form the major structural compounds of the body. The remaining essential elements iron (Fe), iodine (I), copper (Cu), manganese (Mn), zinc (Zn), cobalt (Co), molybdenum (Mo), chromium (Cr), selenium (Se), vanadium (V), fluorine (F) and silicon (Si) are called trace elements. The trace elements are present in very small amounts, ranging from a few milligrams in adult humans. Finally, measurable levels of some elements are found in humans but are not required for growth or good health. Thus, our calculated Geo-accumulation Index (I_{geo}) is based on Co, Pb, Cr, Cu and As from soils and vegetables of Ngazun Township area. Our results I_{geo} values are less than zero. Therefore, the study area is safe.

Table (1) The Element Concentration in Rice & Soil Samples

Rice & Soil Sample	Element				
	Cr	Co	Cu	As	Pb
S1			10		
S2	74	37	18	4	21
S3	73	56	17	4	17
$I_{geo} = \log_2 C_n / 1.5B_n$	-1.019	0.925	-2.058	-2.285	-0.514
B_n =	100	20	50	13	20

Table (2) The Element Concentration in Pigeon-Pea & Soil Samples

Pigeon-Pea & Soil Sample	Element				
	Cr	Co	Cu	As	Pb
S4			15		
S5	94	37	9	3	13
S6	82	56	16	5	14
$I_{geo} = \log_2 C_n / 1.5B_n$	-0.674	0.9	-2.228	-1.963	-1.099
B_n =	100	20	50	13	20

Table (3) The Element Concentration in Chick-Pea & Soil Samples

Chick-Pea & Soil Sample	Element				
	Cr	Co	Cu	As	Pb
S7			13		
S8	62	39	13	3	16
S9	79	39	16	4	16
$I_{geo} = \log_2 C_n / 1.5B_n$	-0.925	0.378	-2.228	-2.285	-0.906
B_n=	100	20	50	13	20

Cr= Chromium, Co= Cobalt, Cu = Copper, As = Arsenic, Pb = Lead, B_n = background or pristine value of the element

Table (4) Maximum allowable limit of heavy metal concentrations in soil (mg/kg) for different countries

Country	Maximum allowable limit of heavy metals concentrations in soil (mg/kg) for different countries								
	As	Pb	Hg	Cd	Cr	Cu	Zn	Co	Ni
Germany	50	70	0.5	1	60	40	150	n.a	50
Poland	n.a	100	n.a	3	100	100	300	50	100
UK	32	450	10	10	130	n.a	n.a	n.a	130
Australia	20	300	1	3	50	100	200	n.a	60
Taiwan	60	300	2	5	250	200	600	n.a	200
Bulgaria	10	26	0.03	0.4	65	34	88	20	46
Canada	20	200	0.8	3	250	150	500	n.a	100

China	30	80	0.7	0.5	200	100	250	n.a	50
Tanzania	1	200	2	3	100	200	50	n.a	100
FAO/WHO Guidelines	20	100	n.a	1	100	100	300	50	50
EU Guidelines	n.a	300	n.a	3	150	140	600	n.a	75
South Africa	5.8	20	0.93	7.5	6.5	16	240	300	91

Results

All samples were analyzed by using EDXRF, it can be measured virtually every element from Mg to U. 30 elements are found in each sample the analyzed results. These elements contain 16 heavy elements and 14 light elements.

Average concentrations of analyzed results in $mgkg^{-1}$ from different samples of the Ngazun Township area are shown in Table (1), (2) and (3). The minimum concentration ranges were as follows; Co (37 $mgkg^{-1}$), Pb (13 $mgkg^{-1}$), Cr (62 $mgkg^{-1}$), Cu (9 $mgkg^{-1}$) and As (3 $mgkg^{-1}$) respectively. The concentrations were used to calculate Geo-accumulation Index (I_{geo}). The results presented show that the average concentrations of heavy metals in soil as well as vegetables from the Ngazun Township area varied and decreased in the order Co>Pb>Cr>Cu>As. Compared with recommended maximum allowable limits for Taiwan and other countries are shown in Table (4). Our calculated results were found to be the lowest in the present area.

Conclusion

Sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), chlorine (Cl) and phosphorus (P) are essential elements for human life. Because they provide essential ions in body fluids and form the major structural compounds of the body. The remaining essential elements iron (Fe), iodine (I), copper (Cu), manganese (Mn), zinc (Zn), cobalt (Co), molybdenum (Mo), chromium (Cr), selenium (Se), vanadium (V), fluorine (F) and silicon (Si) are called trace elements. The trace elements are present in very small amounts, ranging from a few milligrams in adult humans. Finally, measurable levels of some elements are found in humans but are not required for growth or good health. Thus, our calculated Geo-accumulation Index (I_{geo}) is based on Co, Pb, Cr, Cu and As from soils and vegetables of Ngazun Township area. Our results I_{geo} values are less than zero. Therefore, the study area is safe.

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