Toxic Heavy Metal And Salinity Assessment In Water, Soil And Vegetables Around Meki Irrigation Farms

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Abstract: The concentration Heavy metals (Pb, Cr, Cd), macronutrients (Na, K, Ca) and physicochemical properties (Temp., pH, EC, TDS) of soil, vegetable and water were investigated using standard procedures. Soil sample was taken using auger with 0 - 20 cm depth, using zigzag method. To determine the statistical differences between more than two groups of data ANOVA were used and t-test were also used to compare between two groups of data. And each vegetables sample was collected from the same place where a soil sample was taken. Uncultivated area was taken as control. Except, potassium, all physicochemical parameters for both ground (GW) and surface water (SW) were within recommended range of the standards (WHO and FAO) for agricultural use. The pH for GW as well as SW was slightly alkaline. Except Pb, Heavy metals concentrations for soil and vegetables samples were below the safe limits for human consumption. This high Pb levels in meki may probably attributed to more vehicular exhaust fumes. But, when statistically evaluated, using ANOVA, heavy metals concentration in soil samples were all significantly different ($P<0.05$) from Controlled (uncultivated) area. This shows that anthropogenic activities leading cause of metal emission. The concentration of macronutrients for soils and vegetables analyzed in all parts are within the range set up by the standards. The main purpose of this work is to know the sources of heavy metals emission and to control it using different methods.

Key words: Heavy metals, Salinity, Soil, Vegetables, water

1. Introduction

In Ethiopia the industrial sector has contributed much economic development for about twenty years, but agriculture has been the main base for Ethiopia economy, especially in the intensively farmed areas. The rapid development of industry and Long term irrigation, however, has resulted in a lot of waste going into drains, which pollutes the environment [1]. As indicated by [2, 3], this rapid development of industry and Long term irrigation lead to the accumulation heavy metals. And accumulations of heavy metal (Cu, Fe, Mn, Ni Co, Cr, Mo, Se and Zn) will pollutants agricultural soils and are proved detrimental effect beyond a certain limit [4, 5]. Like organic contaminants, heavy metals cannot be degraded and they have toxic effects at low concentrations [6]. The metals accumulate in the salt marshes from polluted air via rain, near roads via splash water or by irrigation with waste water and fertilization with animal wastes. After a long time these sources enrich heavy metals in soil. Pollution of agricultural soils by heavy metals may lead to reduced yields and elevated levels of these elements in agricultural products and thus provide their entrance into food chain and endangering public health and living environment [7, 8]. Soil salinity is a major environmental factor causes reduction in plant growth and productivity in arid and semiarid areas of the world.

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As reported by [9, 10] approximately 1/2 of the world irrigated lands are reported to be seriously affected by salinity and water logging. In general, high salt concentration in soils causes reduction in osmotic potential, which lead to disturb water availability to root cells and make difficulties for plant to obtain both water as well as nutrients. Consequently, a rapid reduction happens in growth rate, productivity and many metabolic changes due to hormonal signal generated by the roots [11, 12]. According to the explanation of some peoples in Meki irrigation form area, when their animals drink water from the river they will infected by different. In addition peoples who regularly get into the river for collecting sand of construction are wounded on their foot. These may be due to contamination of the water by different chemicals and it also may result in contamination of soil of the irrigation farms. For conservation, management and recovery of the area there is a requirement for knowledge of soil chemistry. This study is aimed to investigate the assessments of heavy metal concentrations and Salinity of soils around Meki irrigation farms.

2. Material and Methods

2.1. Study Sites

Field surveys were conducted on Meki farm lands, in the year 2015 and 2016 during the long dry season (November-May). Four farming sites (Wacu, Chefe, Girisa, and Bekele) were selected for the study (Figure 1). Each of the sites was about 2 hectare in size, had been cultivated for more than 20 years and they are present less than 400 m from a road with heavy vehicular movements. The main irrigation water sources are Meki lake water and ground water. In addition, there were scrap metal dealers, automobile repair and vehicle washing activities around the wastewater irrigated sites, while for the groundwater irrigated site there was a municipal (domestic) waste dumping site in close proximity.

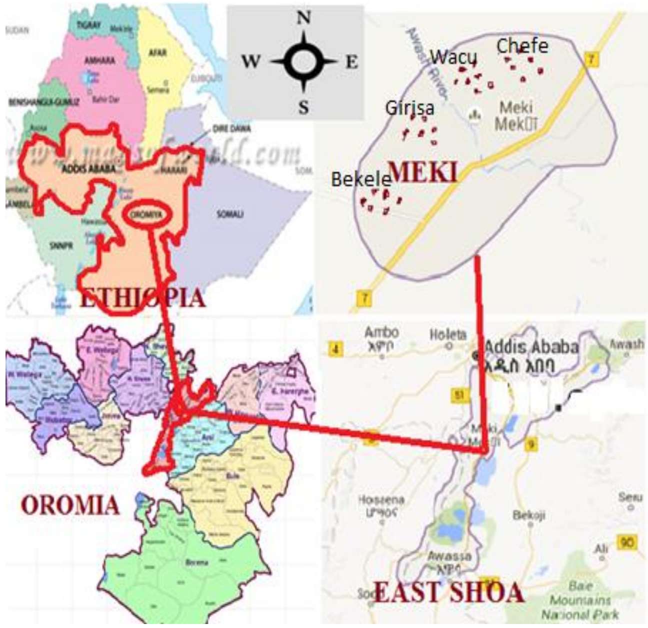

Figure 1.*Study Sites (Soil sampling areas) in Meki City (Chefe, Wacu, Girisa, and Bekele)*

The soil texture on the study sites varied largely between clay and sand extremes. Almost all of the farmers on the study sites use motorized pumps for lifting water to ponds and ground as well as for irrigation. Chemical fertilizers were predominantly used as a source of fertilizer and sometimes organic manure was used whenever there was shortage of chemical fertilizers.

2.2. Soil Sampling, Preparation and Analysis:

For this study, 4 major sampling sites were selected along the lake. From each site, about 250 g of soil samples was collected from alternate left and right sides of the lake. The depth from which the soil was taken was 0–20 cm using sampling instruments (auger). Sampling was done with a plastic spate and packaged into transparent plastic bags and transported to the laboratory in bigger plastic using simple refrigerator. From each site, 5 sub-samples were gathered from 10 m apart. Each sample was taken using zigzag method with 1m apart. All the collected samples were dried for 3 days on air, ground, sieved through a 2 mm sieve and kept for further analysis in refrigerator. pH was determined using pH-meter (model, 181, serial No.0708149, UK) and it was calibrated using standard pH 4, 7 and 9 buffer solution. About five gram of soil sample was weighted and kept in beaker containing 25 mL of distilled water, so it forms 1:5 soil/water suspensions [13]. Using mechanical shaker the mixture was stirred well and left for about 30 minutes, and then the pH was determined by inserting the electrode in to a supernatant solution. For each soil sample, salinity was determined from electrical conductivity (EC) measurements in soil/water suspensions. EC of soil/water suspensions was measured by using distilled water in soil saturated paste extract, 1:5 ratios [13]. After mixing, soil saturated pastes were left to stand for overnight before filtration. Soil/water suspensions were shaken automatically for 1 hour and then filtered through Whatman no. 540 filter paper [14]. EC were measured by using a calibrated conductivity meter connected to an EC electrode. EC readings by Sigma probe were stored electronically and the average of three readings per sample was taken. For Pb, Cd, and Cr two grams of the soil samples were weighed into digestion tube. The soil samples were digested using of 20 mL of a mixture of HCl and HNO_3 (3:1 ratios) and 10 mL of 30% H_2O_2. The H_2O_2 was added in small portions to avoid any possible overflow leading to loss of material from the beaker. The beakers was covered with a watch glass, and heated over a hot plate at 90°C up to clear solution obtained for about two and half hours. After filtration the sample was diluted in 100 mL of volumetric flask using distilled water. All of the above processes were also used for blank solutions, except addition of the analyte. All samples and blanks were stored in plastic containers. Then the metal concentrations were determined by using atomic absorption spectrophotometer (pg instrument ASS500F, S/N 20-0930-21-0020) [15].

2.3. Vegetables Sampling, Preparation and Analysis

Onions were sampled from each of the four study sites. Each vegetable samples collected from the same vegetable beds from where soil samples was taken. To remove the pollutant it was washed several times with tap water and distilled water. And it was sliced into small pieces and dried on air to eliminate excess moisture and in oven at 105°C. The dried sample was ground in a mortar and pestle and finally stored in polyethylene bags in refrigerator further analysis. For heavy metal analysis 0.5g of vegetable sample was digested in furnance at 500oC for four hours, and then 10mL of 6M HCl were added, covered and heated on a steam bath for 15 minute in fume hood. Another 1mL of HNO_3 was added and evaporated to dryness by continuous heating for one hour to dehydrate silica and completely digest organic compounds. Finally, 5mL of 6 M HCl and 10mL of water were added and the mixture was heated on a steam bath to complete dissolution. The mixture was cooled, filtered into a 50mL volumetric flask and made up to the mark with distilled water [16]. Then the samples were analyzed for heavy metals (Cr, Cd, &Pb) concentrations. Chromium was analyzed at wavelength of 357.87 nm, Cadmium at 228.80 nm, and Lead at 283.31 nm [15].

2.4. Water Sampling, Handling and Analysis

For water analysis, twelve samples from lake water and twelve samples from ground water was collected at four different locations (Wacu, Chefe, Girisa and Bekele) with three replications. About 2 mL of 10 percent HNO_3 acid was added to each 500 mL plastic bottle to avoid microbial activity17 before adding Lake Water. Surface composite samples of water were taken from the lake diverted to vegetable farms. All water samples were labeled, stored in plastic bottles, transported to the laboratory and kept in a refrigerator at 4 °C before analysis. Physicochemical parameters such Temperature, pH and EC were measured at the site of collection. The pH was measured using ELMEIRON IP67 waterproof pH meter (CP-105).

2.5. Cations Analysis by Flame Photometry

In this study the metals (Na, Ca and K) was analyzed by Flame Photometry (FP902, Model 1382, S/N 1208037). First mixed standard solution of Na^+, K^+, and Ca^{+2} were prepared by dissolving 254.2 mg of NaCl, 190.6 mg of KCl, and 276.9 mg of $CaCl_2$ in 1 liter of water. In flame photometric analysis the element to be analyzed is being burnt in presence of a given flame, the burnt element gives its characteristic colored flame which is being analyzed. Calcium was analyzed at a wavelength unit of (622nm), Potassium at (766 nm) and Sodium at (589 nm).

2.6. Quality assurance

The quality assurance was done by spiking the digested samples with heavy metals standard solution. For this purpose 1000µg/g stock solution were used to prepare several 60µg/g standard solutions of heavy metals. The spiked samples then digested following the same procedure which is used for soil and vegetable samples. Appropriate quality assurance procedures and precautions were taken to ensure the reliability of the results in all soil, water and vegetable sample test. Samples were carefully handled to avoid contamination. All glassware was socked in acids and rinsed with distilled water. And throughout the analysis analytical grade reagents were used. Reagent blank determinations were used to correct the instrument readings.

2.7. Statistical Analysis

To determine the statistical differences between more groups of samples, analysis of variance (ANOVA) was used. From the obtained result for both soils and vegetables, the average values in the same rows between letter bb and ab are significantly different and between letter aa are not significantly different (table 1 and 2). The Fisher's least significant difference (LSD) test was used at $P < 0.05$ significance level. For water analysis to compare the statistical differences between two groups of samples unpaired t-test was used [18].

3. Results and Discussion

3.1. Physicochemical Properties of Soil and Vegetables

The physicochemical properties of soils and vegetables from all sites were indicated in Table 1 and 2. The mean observed values of temperature for wacu, Chefe, Girisa, Bekele and Control areas was 23.17, 23.87, 26.57, 24.53and25.56, respectively, which is in between the range recommended by FAO [19].

Table 1. *Chemical properties and Nutrients concentrations for soil*

Parameters	Soil					
	Wacu	Chafe	Girisa	Bekele	Control	Std
Temp. (^{o}C)	^{a}23.17±0.603	^{a}23.87±0.568	^{b}26.57±0.063	^{b}24.53±0.063	^{b}25.56±0.123	---
pH	^{b}8.25 ±0.040	^{a}6.76 ±0.070	^{a}6.88 ±0.041	^{b}7.72 ±0.068	^{b}7.32±0.107	5.8-8.3
EC (µs/cm)	^{b}805±11.78	^{b}532.67±8.020	^{b}722.33±7.023	^{b}936.67±6.658	^{b}365.54±3.512	10-30
TDS(µg/g)	^{b}516.33±6.506	^{b}346.32±7.937	^{b}462±4.163	^{b}605±2.646	^{b}236.67±3.605	<1
Na^{+}(µg/g)	^{b}63 ±1.527	^{a}23 ±0.577	^{a}27 ±1.000	^{b}49±1.527	^{b}26±0.5735	---
K^{+}(µg/g)	^{b}113±3.605	^{a}131 ±1.527	^{a}132±2.081	^{b}126 ±3.511	^{b}83±3.055	---
Ca^{+2}(µg/g)	^{a}52 ±2.000	^{b}40 ± 1.527	^{b}45 ±1.1547	^{a}51±3.2145	^{b}21±2.080	---
Pb(µg/g)	^{b}202.5±1.609	^{b}113.6 ±0.2081	^{b}164.2 ±0.300	^{b}132.5±0.100	^{b}1.3±0.050	100
Cd(µg/g)	^{b}0.231 ± 0.001	^{a}0.006 ± 0.0001	^{a}0.0054 ± 0.00015	^{b}0.010± 0.0025	BDL	3
Cr(µg/g)	^{b}0.079 ± 0.0002	^{b}0.127 ± 0.0036	^{b}0.098 ± 0.0035	^{b}0.308± 0.0015	BDL	100

Means in the same rows b/n letter bb and ab are significantly different and between letter aa are not significantly different (P > 0.05)

pH affects mineral nutrient, soil quality and much microorganism activity. Measurement of it shows the acidity and basicity of the soil. From the evidence available, neither a high pH (above 8.4) nor low pH (below 5.0) is favorable for maximum yield of vegetable. The higher soil pH is not favorable for the transference of heavy metals from soil to vegetables [20]. In this study the pH of the soil was slightly acidic (pH 6.76), nearly neutral (pH 7.72) and basic (8.25) respectively, for Chafe, bekele and wacu. A trend in soil pH of sampled site was chefe (6.76) < girisa(6.88) < control (7.32) <bekele(7.72) <wacu (8.25). The measurement of electrical conductivity (current) gives a clear idea of soluble salt present in the soil. The average conductivity of soil was recorded as 805, 532.67, 722.33, 936.67and 362.54µs/cm, for wacu, chefe, girisa, bekele and control, respectively; and TDS for respective site were recorded as 516.33, 346.32, 462, 605, and 236.67.

3.2. Concentrations of Heavy Metals in Soils and Vegetables (Onions)

The results of heavy metal content in soils and vegetables were indicated in table 1 and 2, if soils pH is near neutral region the vegetables which planted on it will not consume heavy metals through their roots, so, the concentration of heavy metals will become high on soils [21].

Table 2. *Chemical properties and Nutrients concentrations for vegetables*

Parameters	Vegetable				
	Wacu	Chafe	Girisa	Bekele	Std
pH	^{b}4.7 ±0.097	^{a}3.85 ±0.1228	^{a}3.86 ±0.1069	^{b}4.3 ±0.1286	---
EC (µs/cm)	^{b}446 ±3.785	^{b}421 ±3.511	^{b}385 ±4.582	^{b}543 ±1.527	---
TDS(µg/g)	^{b}285 ±2.516	^{b}270 ±2.309	^{b}247 ±3.055	^{b}348 ±2.646	---
Na^{+}(µg/g)	^{b}3.79 ±0.030	^{b}2.26 ±.0208	^{b}3.12 ±0.020	^{b}3.43 ±0.030	---
K^{+}(µg/g)	^{b}45.1 ±0.707	^{b}33.8 ±0.458	^{b}43.5 ±0.945	^{b}39.6 ±0.723	---
Ca^{+2}(µg/g)	^{b}6.11 ±0.070	^{b}5.32 ±0.020	^{b}5.62 ±0.036	^{b}3.22 ±0.030	---
Pb(µg/g)	^{b}0.732 ±0.0035	^{b}0.367 ±0.0036	^{b}0.234 ±0.0015	^{b}0.331 ±0.004	0.3
Cd(µg/g)	^{a}0.0055 ± 0.0003	^{b}0.0023 ± 0.002	BDL	^{a}0.006 ± 0.0004	0.2
Cr(µg/g)	^{b}0.063 ± 0.0066	^{b}0.100 ± 0.0036	^{b}0.077 ± 0.0016	^{b}0.630 ± 0.085	0.05

Means in the same rows b/n letter bb and ab are significantly different and between letter aa are not significantly different (P > 0.05)

Except Cr for wacu, low concentrations of heavy metals were recorded in vegetables than soils; this is the same with result obtained on [22]. In all samples, except Girisa in soil, the concentrations of Pb in both vegetables and soils were recorded above the FAO/WHO[23], permissible limit. These high levels of Pb may be due to the presence of vehicular exhaust fumes [24].In all vegetable samples, the concentrations of Cd are below permissible limits. As reported by [25], if the pH values of the soil are not acidic, due to mobile behavior of Cd, it will be easily absorbed by roots and distributed in side of plants. In all areas the concentrations of Cr were above permissible limits [26, 27]. Similar levels of elevation were reported for chromium on studies conducted in Varanasi, Harare and Addis Ababa [28]. But the concentration of Cr in all soils was bellow permissible limits. The concentration of all heavy metals in soil samples significantly higher than the Uncultivated (control) area concentrations. This indicates heavy metal contamination in the agricultural soils of Meki is due to long-term agricultural activities.

3.3. Physicochemical Properties of Water

Table 3 shows the physicochemical properties of water. The temperature values for SW and GW was 23.43 & 27.66 ^{o}C and pH values was 7.8 & 7.63, respectively, which is in between the range recommended by FAO [19] for irrigation water. The average values of electrical conductivity for surface water is 668 µs/cm and average value for ground water is 1432 µs/cm. EC for surface water was considered slightly normal and little to moderate salinity problems for ground water. Therefore, the EC of ground water according to this limited could be caused moderate salinity problem. Indeed to combat this salinity it is possible to apply normal water to remove the salts from the root zone by leaching [29]. The concentration of TDS in this study is 428 and 917 for SW and GW, respectively. When the values of TDS obtained for GW was compared with the values obtained for SW it is slightly saline for irrigation purpose, but the value for both of them is lower than FAO standard according to which maximum permissible limit (2000 mg/L) for irrigation water.

Table 3. *Chemical properties and Nutrients concentrations for water*

Parameters	Water		
	Surface	Ground	Std[34]
Temp.(^{o}C)	^{b}23.43±0.100	^{b}27.66±0.351	---
pH	^{b}7.83 ±0.0208	^{b}7.64 ±0.042	6.5-8.4
EC (µs/cm)	^{b}668 ± 4.358	^{b}1430 ±6.557	0-3000
TDS(mg/L)	^{b}428 ±2.516	^{b}917 ± 3.785	0-2000
Na^{+}(mg/L)	^{b}236 ±3.605	^{b}77 ±0.2645	900
K^{+}(mg/L)	^{b}11.6 ±0.305	^{b}23.9 ±0.435	0.2
Ca^{+2}(mg/L)	^{b}9.6 ±0.0611	^{b}24.7 ±0.435	400
Pb(µg/g)	^{b}0.333 ±0.003	^{b}0.286 ±0.001	5
Cd(µg/g)	^{b}0.005 ±0.0002	^{b}0.087 ±0.003	0.01
Cr(µg/g)	BDL	BDL	0.1

Means in the same rows b/n letter bb and ab are significantly different and between letter aa are not significantly different (P > 0.05)

3.4. Heavy Metal Analysis for Water

The mean heavy metal concentrations of water from the two water irrigation sources are given in Table 3. The average value of Pb content of ground water and lake water was 0.333 and 0.286 mg/L, respectively. The standard for irrigation water approved by FAO/WHO for Pb is 5 mg/L. These results shows that Pb content of lake water as well as ground water were found in safe range and can be used for irrigation without any hazards. The concentration of Cr for both Ground water and lake water was BDL. The standard for irrigation water approved by FAO/WHO [27] for Cr is 0.1 mg/L. For neutral to alkaline soil, the results show that Cr content of Ground water and lake water were found in safe range. The average value of Cd content of ground water and lake water was 0.005and 0.087 mg/L, respectively. The standard for irrigation water approved by FAO/WHO for Cd was 0.01 mg/L. These results shows that Cd content of lake water were found in safe range and can be used for irrigation without any hazards. But, for ground water, the value is somewhat higher than the permissible limit.

3.5. Macronutrients Analyses by Flame Photometry

The concentration of cations in water used for irrigation was highest for Na, followed by Ca and K for lake water and Na, followed by Ca and K for ground water table 3. The concentration of cations in vegetables was highest for K, followed by Ca and Na and for soil same trends were observed like vegetable except Na in wacu site which shows some increments than vegetables. Except K, the concentration of Na+ and Ca^{+2} for both ground and lake water was below the acceptable range (FAO/WHO) recommended for irrigation [30].

4. Conclusion and Recommendations

Analysis for physicochemical properties (Temp., pH, EC, TDS), heavy metal concentration (Pb, Cr and Cd) and major nutrients (Na, K, and Ca) were done using standard procedures in the vicinity of Meki agricultural site. The concentration of heavy metals for ground water is relatively larger than lake water. Except Pb, Heavy metals concentration in soils and vegetables are within permissible limits (FAO/WHO). But using ANOVA when statistically compared the concentration for all samples were significantly different than control (uncultivated area) heavy metal soil concentrations; this shows that anthropogenic activities was the first source for metal emission. For ground and lake water, the macro nutrients analyzed in all soil, vegetables and waters are within the range set up by the WHO/FAO. So from this it's possible to conclude that, except Pb, for today Meki soil and water is well suited for vegetable irrigation without any hazardous effect on people. But as recommendation if care is not taken or if long-term agricultural activities, more vehicular exhaust fumes, the municipal compost...etc is regularly added in farm land, the concentration of these heavy metals will increases and it will become dangerous for the communities. So, some safe ways should be used for the disposal of these wastes.

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