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Monitoring Heavy Metal Pollution at Al-Buraihi Sewage Station in Taiz, Yemen Using Napier Grass (*Pennisetum Purpureum Schumach*) as a Bioindicator

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ABSTRACT

Soil pollution or soil contamination is an important environmental concern that causes health for both flora and fauna worldwide. The majority of pollutants have anthropogenic origins. However, some contaminants can occur naturally in soils as components of minerals and can be toxic at high concentrations. The biological materials like microorganisms, plants and animals have been studied to be used in biomonitoring of pollution. Plants are important bioindicators for heavy metals environmental pollution. Napier grass (Pennisetum purpureum Schumach), an animal fodder in Yemen, has been used in this study as a bioindicator for monitoring soil pollution around Al-Buraihi sewage station, Taiz, Yemen, using inductively coupled plasma-optical emission spectrometry (ICP-OES) technique. The concentrations of Cr and Pb were acceptable in all samples according to FAO and WHO, while those of As, Cd, Co, Cu, Fe, Mo, Ni, Se, and Zn were exceeding the limits of WHO in all plant species samples and accordingly recommended not to be used as animal fodder.

1. Introduction

The term soil pollution implies the occurrence of a chemical/ foreign substance at a higher concentration than the normal having adverse effects on life. Most of the pollutants are anthropogenic origin. Even, there are contaminants which are natural origin in the soil as

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components of minerals. These contaminants on higher concentrations are toxic. Soil contamination occurs when the concentration of a chemical or substance is higher than would occur naturally but is not necessarily causing harm (Rodriguez-Eugenio et al. 2018; N et al. 2018; McLaughlin et al. 2004). Sources of soil pollution include domestic and municipal wastes, industrial and mining wastes, agricultural wastes, radioactive materials and biological agents such as the excreta of humans, animals and digested sewage sludge.

Accumulation of heavy metals in the surrounding can be considered an important environmental pollutant. These heavy metals are toxic, non-degradable and bio-accumulative. Heavy metals are the important environmental pollutants causing pollution problems by increasing their use in products in recent decades(Liang et al. 2011; Galavi et al. 2010). These at a higher concentration generally inhibit plant growth and overall physiological processes. Heavy metals are harmful to human health and the threat to both plant and animal life (Sardar et al. 2013; Hashim and Chu 2004; El-Sheekh et al. 2003). The sources of heavy metals in the environment are natural, agricultural, industrial, domestic effluent and atmospheric sources. The important natural sources of heavy metals are geologic parent material, rock outcroppings, volcanoes, wind dust or wind-blown dust and volcanic eruption. The anthropogenic activities include mining, smelting, pesticides, organic and inorganic fertilizers(Nagajyoti et al. 2010). Besides, some of the heavy metals are essential micronutrients for plants and animals such as Fe, Co, Cu, Mn, Mo, Ni and Zn, their uptake in excess to the plant requirements resulting in toxic effects. They are also called as trace elements due to their presence in trace (10 mg kg^{-1} or mg L^{-1}) or ultra-trace (1 µg kg^{-1} or µg L^{-1}) quantities in the environmental matrices(Nagajyoti et al. 2010).

Monitoring of heavy metals in environmental samples is crucial since most of these heavy metals have negative or positive effects on human health even at very low concentrations (Nomngongo et al. 2013). Nowadays, the increasing use of waste chemical and industrial drainage systems represents the most dangerous chemical pollution. Metal contamination of both aquatic and terrestrial ecosystems is a matter of concern because it is widespread and potentially deleterious to aquatic and terrestrial life. Heavy metals can even modify the structure and productivity of both aquatic and terrestrial ecosystems(Koukal et al. 2003; Inthorn et al. 2002). The detection of environmental pollution using biological materials as indicators is a cheap, reliable and simple alternative to the conventional sampling methods(Pinto et al. 2003). Plants can be used as bioindicators for toxicity assessment in aquatic and terrestrial ecosystems(Zurayk et al. 2001). The use of higher plants as biomonitors or bioindicators of heavy metal pollution in the environment has been increased in the past few decades (Pugh et al. 2002; Swaileh et al. 2004; Paoletti 1999). Biological monitoring gives information about the integrated effect of all environmental factors on living organisms. In this article, the contamination of plant species, Napier grass, with heavy metals in the Al-Buraihi sewage station in Taiz, Yemen, is described. Napier grass was selected as a bioindicator for the assessment of the heavy metals contamination.

2. Study Area

Yemen is one of the countries in the world located within the arid and semi-arid areas and characterized by limited and the scarcity of water resources. Yemen suffers from a water problem for drinking and irrigation because of the steadily increasing the population growth and lack and depletion of available water resources (Hamoda 2004). When it comes to the competition in water needs for either drinking or irrigation, it will go to the drinking purpose other than irrigation. This, of course, harms irrigated agricultural land and as a result of agricultural outputs since the agricultural activity is a key to food security worldwide (Hamoda 2004; Chuma et al. 2015). Yemen is one of the countries facing lack of water hence the reuse of treated wastewater may help in facing a water crisis. Farmers at Al-Buraihi area in Taiz, Yemen, use untreated wastewater for irrigation of plants. This causes soil pollution and health detrimental to human as well as animals.

Taiz sewage station is located in Al-Buraihi area, northeastern of Taiz lies between longitudes 10 ^{o} 39' and 30 ^{o}39' E and latitudes 80 ^{o} 150' and 80 ^{o}151' N. Al-Buraihi area is located within warm climate semi-dry and the average annual temperature is about 25 ^{o}C (Fig 1). Farmers at Al-Buraihi area in Taiz, Yemen, use untreated wastewater for irrigation of plants. This may cause health detrimental to human as well as animals. Since the wastewater stabilization ponds (WSPs) have been established in Taiz, heavy metals had never been examined. This motivated the authors to monitor pollution of soil around Al-Buraihi sewage station through bioindicator Napier grass (*Pennisetum purpureum Schumach*.).

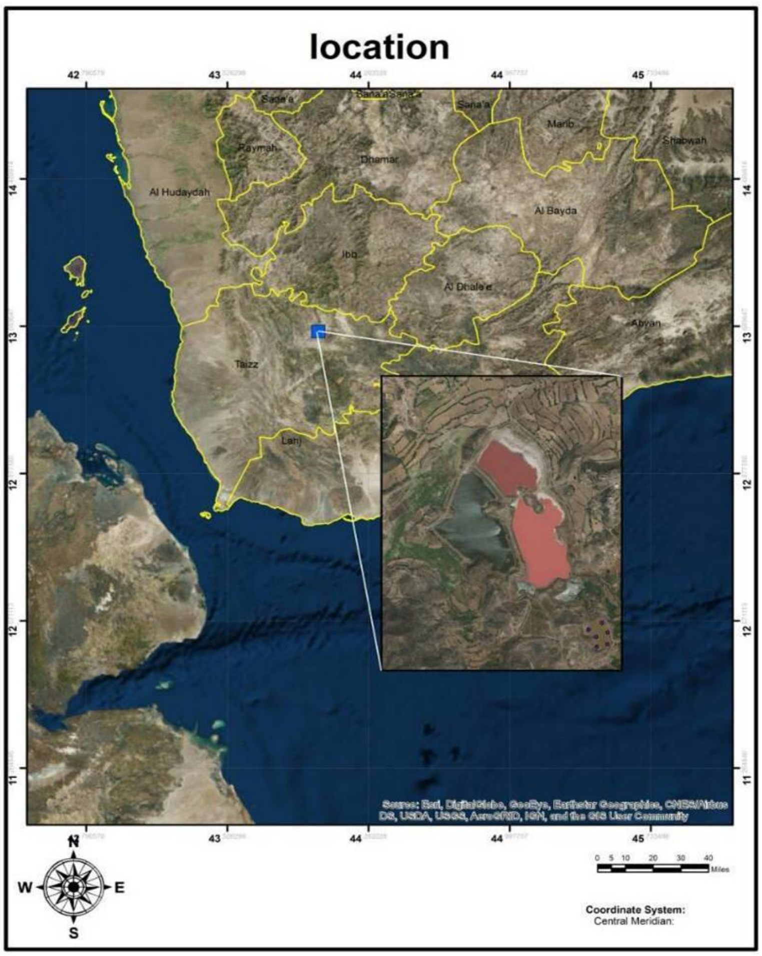

Figure 1. GIS map of the study area

3. Napier grass (Pennisetum purpureum Schumach)

Napier is also known as elephant grass or Uganda grass (Fig. 2). It is a major and highest yielding tropical grass. It is a very adaptable species and can be grown under a wide range of conditions like dry or wet conditions. It is a very important forage in tropical areas due to its high productivity. It is mainly suitable to feed cattle. It's a pioneer species that can be used to control weed (D'Antonio and Vitousek 1992; FAO 2015). It is also used in water storage, to reduce soil losses due to erosion on slopes, pest control and as a biofuel (Francis 2004; Parrott 2005; Adekalu et al. 2007; Khan et al. 2007) .

Figure 2. Napier grass (*Pennisetum purpureum* Schumach)

4. Materials and Methods

4.1. Materials

All chemicals and reagents used in the study were of analytical grade (AR) nitric acid (65% ACS, ISO), perchloric acid (70% ACS, ISO) and sulfuric acid (98% -VWR) extra pure were used. Standard solutions of salts of elements (1000 mg/L) were purchased from Scharlau, Spain. All glassware was soaked in 10% nitric acid and washed with millipore distilled water before use.

4.2. Instrumentation

An inductively coupled plasma-optical emission spectrometer (ICP-OES) with an axially viewed configuration (VISTA MPX, Varian, Mulgrave, Australia) that was equipped with a solid-state detector, Stumar-master mist chamber, and V-groove nebulizer was employed for interested elements determinations using a standard calibration method. The acid digestion of soil samples was performed using a commercial high-pressure laboratory microwave oven (Milestone Ethos 1600 Microwave Labstation, Sorisole, Italy) operating at a frequency of 2450 Hz with an energy output of 900 W and easy control software HPR1000/10Shigh pressure segmented rotor. Electrical conductivity (EC) and soil reaction (pH) were determined *in-situ* using a multipurpose electronic Jenway 4520 Conductivity/TDS Meter and Hanna portable pH meter respectively. Organic matter contents were measured as in Walkey and Black method (Preer et al. 1980; Walkley and Black 1934).

4.3. The sampling of Soil and Plant species

To evaluate the influence of wastewater irrigation on the heavy metal concentrations in soil, twelve samples of soil were collected from the study area. Sampled were collected randomly from the surface soil (0.0-30cm in depth) manually using an auger and carefully packed into polythene bags and eventually brought to the laboratory. Locations of these twelve samples of soil were mapped using GPS instrument and GIS software (ArcGIS10.3) (Fig. 3a).

Plant samples were collected randomly and manually using vinyl gloves and kept in brown bags and brought to the laboratory. The plant samples were rinsed with deionized water and dried in an oven at 70 ^{o}C for 48hrs and then ground to powder. The locations of plant samples collected were recorded (Fig. 3b).

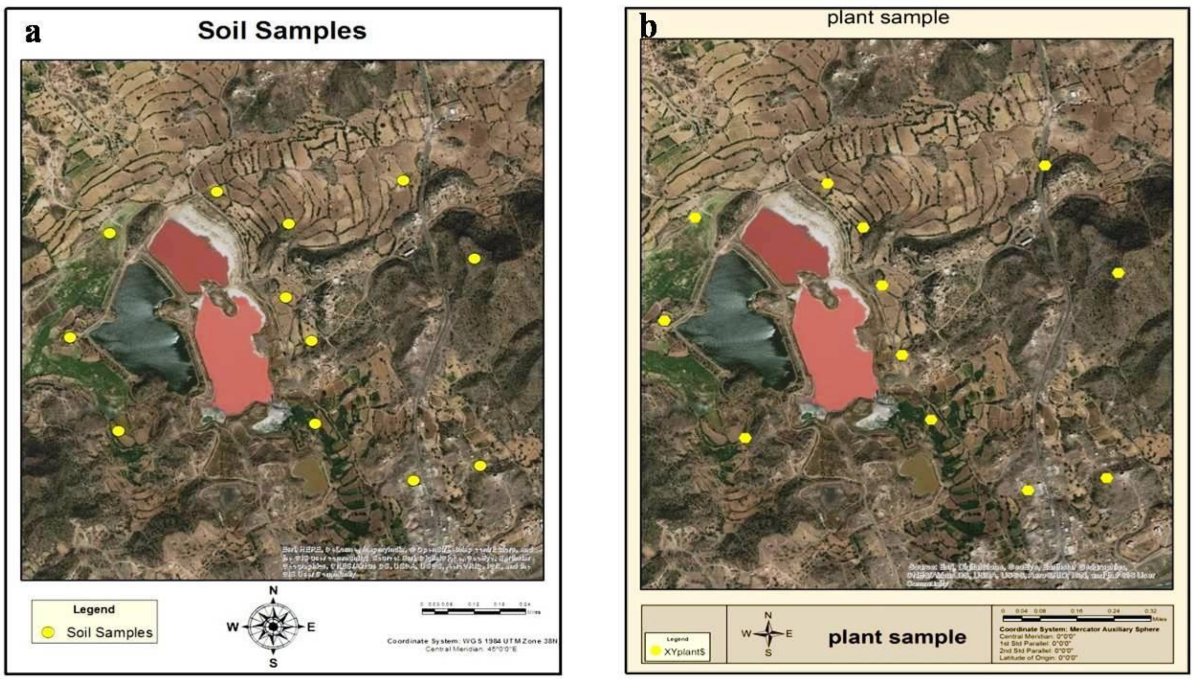

Figure 3: GIS map of locations of a) wastewater and b) plant species samples collected

5. Sample Preparation

5.1. Soil sample preparation

Soil samples were air-dried, crushed and passed through 0.45 mesh sieve and stored at ambient temperature and glass before analysis (Lindsay and Lyman, 1979). The digested samples of soil were diluted to 50mL with distilled water. All reagents used were of analytical grade (AR) and purchased from (Scharlau-JPN) including standard stock solutions of known concentration of different heavy metals. All analyses were done in triplicates.

5.2. Plant species sample preparation

The fresh plant species samples were brought to the laboratory and washed primarily with running tap water, followed by three consecutive washing with distilled water to remove the soil particles. Samples were dried in an oven at 70 ^{0}C for 48 h and then ground to powder. The digested plant species samples were diluted to 50mL with distilled water. Heavy metal concentrations of plant samples were estimated by ICP-OES Varian (Vista-MPX). All analyses were done in triplicates.

6. Statistical analysis

The descriptive statistical parameters, mean, standard deviation, and correlation analysis were calculated using the IBM SPSS version 26 software. The data collected were discussed in terms of average and 95% confidence intervals. Statistical differences between the means were compared using the least significant differences (LSD) at probability $p \leq 0.05$ (significant).

7. Results and Discussion

The Physico-chemical properties and heavy metal composition of the soil samples are given in Table 1. The descriptive statistical parameters, mean and standard deviation, were calculated for all the parameters of the soil sample which is given in Table 2. The graphical representation of the physicochemical parameters is given in Fig 4. From Fig 4 and Table 2, it is evident that the electrical conductivity (EC) of the soil ranged from 1.10 to 5.70 dS/m with a mean value of 6.92dS/m and StDev of 4.34. There are significant differences in EC measurements when EC limits are 1.2 (p=0.000) and 2.4 (p=0.001). Electrical conductivity (EC) of soils irrigated with wastewater was increased due to the higher concentration of electrolytes such as Na^+ and K^+ in wastewater (Mojiri 2011). The pH, values of the soil samples ranged from 5.90 to 7.70 with an average of 7.17. Therefore, the pH of the soil is mostly neutral to mild acidic for all soil samples. There were significant differences in pH values (p=0.002) when the pH was 6.60. However, there were no significant differences in pH values (p=0.368) when the pH was 7.30. The irrigation with wastewater decreased the pH of the soil due to the decomposition of organic matter and the production of organic acids. Soil irrigated with wastewater at first may cause a decrease in the pH of the soil, but later, it may cause an increase in the pH of the soil (Mojiri 2011). Fortunately, in this study, all pH measurements were within the permissible limits according to WHO (WHO 2006). Sodium adsorption ratio (SAR) is a measure of the suitability of water for use in agricultural irrigation, as determined by the concentrations of solids dissolved in the water. It is also a measure of the sodicity of soil, as determined from analysis of water extracted from the soil. The SAR mean value was 4.43, the minimum value was 1.24 and the maximum was 9.23 with StDev of 2.037. There were significant variation differences (p=0.000). SAR is the only factor in determining the suitability of water for irrigation. Generally, higher the sodium adsorption ratio, less suitability is the water for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil (Reeve et al. 1954). The results of this study were within the permissible limits (WHO 2006). Based on organic matter content, soils are characterized as a mineral or an organic. The mineral soils form most of the world's cultivated land and may contain from a trace to 30% organic matter. The organic soils are naturally rich in organic matter principally for climatic reasons. Although the latter contains more than 30% organic matter, it is precisely for this reason that they are not vital cropping soil. The results showed that the mean organic matter value was 31.24 and the minimum value was 14.71 and maximum value 42.14 of the analyzed samples of soil with StDev of 8.56 and significant variation differences (p=0.000) between the studied samples. Most samples readings were higher than the permissible limits(WHO 2006). The irrigation with untreated wastewater increased OM content of soil (Mojiri 2011). From the results of this study, Al-Buraihi's soil can be classified as organic soil according to FAO limits(Rodriguez-Eugenio et al. 2018).

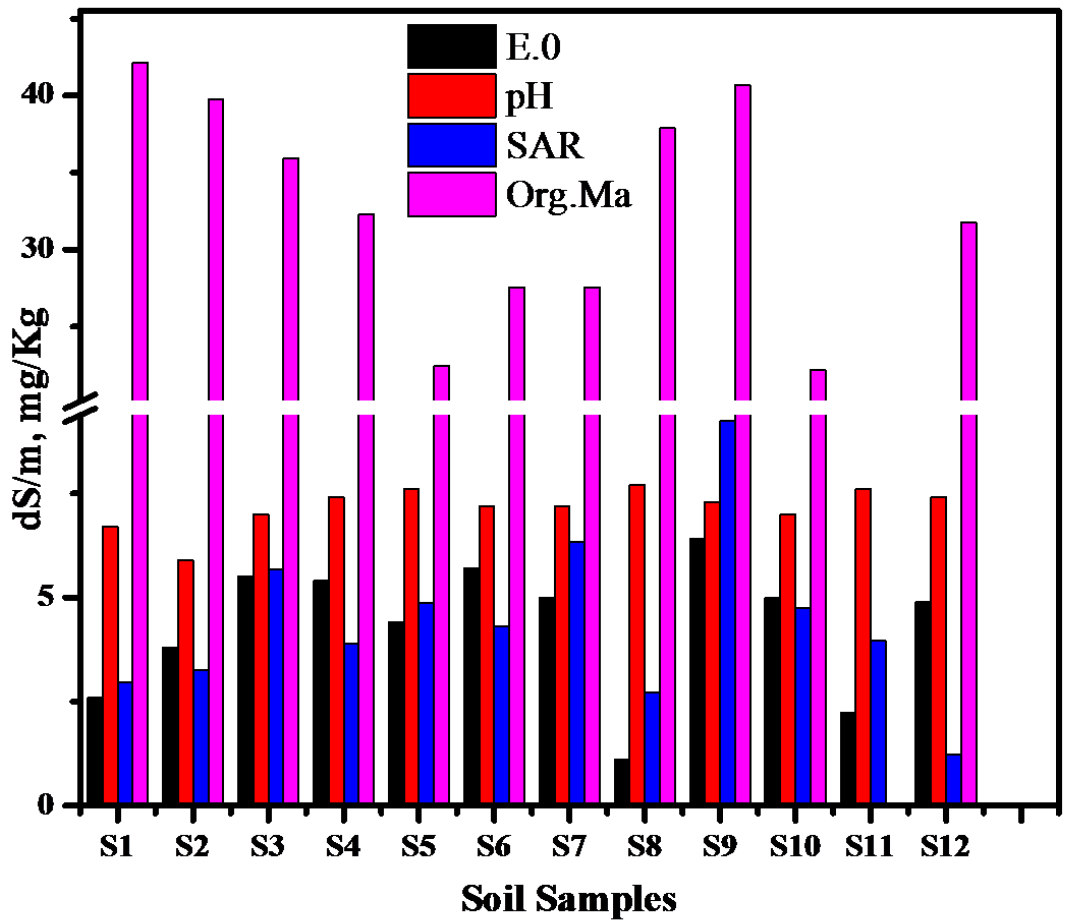

Figure 4. Physicochemical parameters of soil samples

7.1. Elemental analysis

The measured concentrations of major elements in the different soil samples are given in Table 2. The results of this study showed that half of the elements investigated were fallen within the permissible limits recommended at least by one of these standards of the World Health Organization (WHO 2006) and others (CCME 2007; Alzoubi et al. 2013; H. Bowen 1979). These elements include the macronutrients (K, Ca and Mg) and micronutrients (Ba, Cd, Co, Cr, Fe, Mn, Ni, Pb and Sr).

On the other hand, the concentrations of the other group of elements were all exceeded the permissible limits recommended at least by one of the above-mentioned standards. These elements are heavy metals such as Ag, As, B, P, Cu, Mn, Mo, Sb, Sc, Se, Sn and Zn.

Table 1.

ICP results of the soil samples collected around Al-Buraihi sewage station

Heavy metals	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
Ag	22.500	8.412	4.023	2.559	1.301	2.212
Al	6607.046	7012.326	6164.324	3072.491	5901.064	5014.649
As	7.775	11.893	7.672	5.918	14.557	10.891
B	16.776	33.700	14.744	3.035	44.479	40.738
Ba	29.078	21.714	22.639	21.158	22.896	29.335

Cd	1.090	0.767	0.513	0.469	0.715	0.770
Co	0.000	0.000	0.000	0.000	0.000	0.000
Cr	22.110	16.699	16.463	9.432	16.759	16.812
Cu	56.563	37.783	24.536	18.048	30.971	22.537
Po	10440.895	11455.889	9599.630	5759.349	11076.966	11888.279
U	7.127	6.934	7.877	4.215	6.051	7.240
Mn	294.180	222.773	294.371	271.228	325.633	347.470
Mo	0.717	0.713	0.224	0.491	0.434	0.743
NI	21.281	21.712	21.948	11.991	25.625	21.915
Pb	22.528	10.085	3.182	3.058	3.741	3.766
Sb	2.199	1.518	2.094	2.170	1.972	2.412
So	2.275	2.006	3.587	2.368	9.574	4.071
Sn	6.797	7.026	7.064	4.298	8.857	2.699
Zn	210.129	112.630	53.524	32.443	58.205	54.425
Sr	135.054	87.011	239.146	555.422	106.217	219.491
Se	18.727	16.541	16.570	12.983	25.225	17.359
Ca	2908.367	2442.477	3531.033	3848.084	3232.072	3452.992
K	1502.067	1363.736	1951.939	1139.608	2344.416	1834.835
Mg	2512.013	2537.897	2768.344	2625.146	3130.744	2772.320
Na	909.577	971.118	1863.972	1282.502	1630.086	1404.011
P	16100.921	12376.566	18858.595	6160.931	11040.111	15300.943
E.C	2.600	3.800	5.500	5.400	4.400	5.700
pH	6.700	5.900	7.000	7.400	7.600	7.200
SAR	2.969	3.269	5.679	3.889	4.876	4.297
Org.Ma	42.143	39.763	35.913	32.278	22.458	27.560
Soil text.	I.	511	SL	CL	511.	SI.
Heavy metals	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
Ag	15.249	1.719	9.423	2.323	0.000	0.603
Al	7228.855	3481.180	6675.699	8426.157	7174.648	7583.730
As	13.338	5.040	9.650	12.303	7.171	7.310
B	30.108	0.000	49.693	15.372	9.646	14.376
Ba	17.758	27.714	33.344	23.950	24.001	31.573
Cd	0.810	0.380	0.983	0.768	0.580	0.680
Co	0.000	0.000	0.000	0.000	0.000	0.000
Cr	26.198	11.295	43.172	21.128	19.127	20.849
Cu	28.981	14.279	51.460	36.872	23.581	21.416
Po	10069.771	6116.543	11547.884	11708.337	8848474	9497.265
U	9.640	3.782	6.414	7.954	7.247	9.001
Mn	392.207	245.162	356.802	401.504	298.910	374.205
Mo	2.229	0.005	3.027	0.464	0.364	0.253
NI	31.170	12.510	38.417	33.003	24.749	26.802
Pb	5.694	4.849	16.490	5.652	34.309	5.705
Sb	2.337	0.459	2.176	3.302	0.736	1.477
So	7.357	2.637	5.715	5.056	2.133	1.570
Sn	7.381	1.534	5.707	4.373	7.251	0.000
Zn	71.605	39.427	15.837	66.541	38987	47.830
Sr	362.293	93.236	255.676	99.059	135.105	131.666
Se	22.136	13.110	23.095	26.611	20.996	20.591

Ca	3666.041	3226.545	3438.979	3373.564	3274.216	3385.526
K	1920.526	1093.745	1804.765	1922.878	1242.262	1918.303
Mg	2767.890	2191.961	2686.407	2794.511	2645.203	2709.195
Na	2093.279	821.182	2987.249	1548.847	1262.337	399.912
P	12400.760	3713.548	12605.787	6204.968	2495.840	2564.348
E.C	5.000	1.100	6.400	5.000	2.240	4.900
pH	7.200	7.700	7.300	7.000	7.600	7.400
SAR	6.326	2.722	9.232	4.753	3.960	1.237
Org.Ma	27.554	37.882	40.679	22.196	14.71.4	31.783
Soil text.	SCI	SC1	SL	541	CL	SICI.

Table 2.
Descriptive statistics of the elements in soil samples (n=12, mg/kg)

Parameter	Minimum	Maximum	Mean	StDev	Guidelines
Ag	0.000	22.50	5.86	6.904	3.0[b] and 20.0[a]
As	5.040	14.557	9.459	3.091	8.0[b] and 12.0[a]
B	0.000	49.693	22.722	16.509	1.70[b] and 2.0[a]
Ba	17.758	33.344	25.43	4.705	302.0[b] and 750.0[a]
Cd	0.380	1.09	0.71	0.205	4.0[d] and 1.40[a]
Co	0.000	0.00	0.00	0.000	8.0[d] and 40.0[a]
Cr	9.432	43.172	20.004	8.603	64.0[a]
Cu	14.279	56.563	30.586	13.011	20.0[c] and 63.0[a]
Fe	5759.349	11888.279	9834.14	2063.339	37000[c]
Mn	222.773	401.504	318.704	57.300	800.0[c]
Mo	0.005	3.027	0.805	0.895	0.60[b] and 5.0[a]
Ni	11.991	38.417	24.26	7.675	107.0[b] and 50.0[a,d]
Pb	3.058	34.309	9.922	9.747	70.0[a] , 84.0[b] and 35.0[d]
Sb	0.459	3.302	1.904	0.766	20.0[a] , 36.0[b] and 1.0[d]
Sc	1.570	555.422	201.615	2.476	7.0[d]
Se	0.00	9.574	4.029	2.699	1.0[a] and 6.0[b]
Sn	0.00	8.857	5.249	2.699	5.0[a]
Sr	12.983	26.611	19.495	4.395	250.0[d]
Zn	15.837	210.129	66.799	51.106	200.0[a]; 50.0[c] and 90.0[d]
P	2495.840	18858.595	9985.277	5586.823	20[c]
Ca	2442.477	3848.084	3314.99	361.802	14000[c]
K	1093.745	2344.416	1669.923	391.543	13000[e]
Na	399.912	2987.249	1431.173	678.979	300 <[c]
Mg	2191.961	3130.744	2678.469	219.92	6000[c]
EC (dS/m)	1.10	5.70	6.92	3.45	2.0[a]
pH	5.90	7.70	7.17	0.49	6.0-8.0[a]
OM (%)	14.714	42.143	31.244	8.566	1.29 <[c]
SAR (meq/L)	1.237	9.232	4.434	2.037	5.0[a]

[a] Canadian Soil Quality for the Protection of Environmental and Human Health (CCME 2007).
[b] WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater(WHO 2006).
[c] Analysis Methods for Soil, Plant, Water and Fertilizers(Alzoubi et al. 2013).
[d] Environmental Chemistry of the Elements. 1979, Academic Press, New York, USA (H. J. M. Bowen 1979).

Table 2, clearly depicts that Silver (Ag) doesn’t show any significant difference (P=0.179) according to WHO limits, with a mean value of 5.86 and range of 0.00 as a minimum to 22.50 as a maximum with StDev of 6.90. The silver (Ag) originates mainly from small scale photography, household products such as polishes and domestic water treatment devices(Shafer et al. 1998; Adams and Kramer 1999). Similarly, arsenic doesn’t show any significant difference (p=0.130) according to WHO limits, with a mean value of 9.45 and range of 5.04 as a minimum to 14.56 as a maximum, with StDev of 3.09. Arsenic inputs come from natural background sources and household products such as washing products, medicines, garden products, wood preservatives, old paints and pigments. Arsenic is present mainly as dimethyl arsenic acid (DMAA) and as As(III) arsenite in urban effluents and sewage sludge (Thornton et al. 2001). In this study, its level exceeded the permissible limit. This results in toxicity of soil and might travel from plants to animals through biomagnification. Sodium (Na) levels ranged from 399.91 to 2987.24 with mean of 1431.17, StDev of 678.97. The accumulation of sodium in the soil causes the salinity and sodicity of soil and hence affects plants growth(Reeve et al. 1954). Phosphorus (P) values ranged between 2495.84 and 18858.60, the mean of 9985.27 and StDev of 5586.82 with a significant variation (p=0.000). These readings are far higher than the standard value. An excessive amount of phosphorous in the soil is stunted plant growth. It also decreases the plant's ability to uptake Zn and eventually bleaching of plant tissue may occur. Boron (B) shows significant differences (p=0.000) (p=001) according to WHO limits, with a mean value of 22.72 and range of 0.00 as a minimum to 49.69 as a maximum, with StDev of 16.50. Copper (Cu) shows significant differences (p=0.000) according to WHO limits, with mean value 30.58 and range of 14.28 as a minimum to 56.56 as a maximum with StDev of 13.01. The Cu comes mainly from corrosion and leaching of plumbing, fungicides (copper(II) chloride), pigments, wood preservatives and antifouling paints. Molybdenum (Mo) values ranged from 0.01 to 3.03 with mean and st.Dev of 0.80 and 0.89 respectively and the values didn't show significant differences (p=0.444) according to WHO limits. Antimony (Sb) shows significant differences (p=0.000) according to WHO limits, with a mean value of 1.90 and range of 0.46 as a minimum to 3.30 and with StDev of 0.76. Scandium (Sc) levels show significant differences (P=0.000), the mean value of 19.49, the range from 12.98 to 87.01with StDev of 4.39. Selenium (Se) mean value was 4.02 and the range was 1.57 to 9.57 with St.Dev 2.47 and the values didn't show significant differences (p=0.019) according to WHO limits. Selenium is among the potentially toxic metalloids found in urban wastewaters even in low concentration (WHO 2006). These are of importance due to their potential effects on human/animal health. Few studies have had taken these into account (Thornton et al. 2001). Selenium comes from food products, food supplements, shampoos, other cosmetics, old paints and pigments. Tin (Sn) values ranged from 0.00 to 8.86 with mean and StDev of 5.24 and 2.69 respectively and significant differences (P=0.000). The levels of zinc (Zn) ranged from 15.84 to 210.13 with mean and St.Dev of 66.79 and 51.10 respectively and Zn shows sonication differences (p=0.002) according to WHO limits. Although Zn is important for plants in producing chlorophyll but in high levels of zinc cause severe damage to roots of plants which indicated by yellowing and wilting. Also, high levels of zinc inhibit the uptake of iron (Fe), so cause zinc toxicity.

Similarly, the heavy metal composition of the plant samples was performed. The results obtained are given in Table 3. The descriptive statistical parameters, such as mean and standard deviation, were calculated. The results obtained are given in Table 4. The concentrations of As, Cd, Co, Cu, Fe, Mo, Ni, Se, and Zn were exceeding the limits of WHO in all plant samples whereas the concentration of Cr in all plant species was within permissible limits according to WHO(WHO 2006). Fortunately, Pb was not detected in all plant samples investigated since the presence of this element in high concentration can inhibit the growth of plant cell. According to FAO, the maximum permissible limit is 5.0 mg/L, (FAO 1985). The absence of Pb may be due to its concentration in samples was under the limit of detection or may be absent. If it is absent, it may be attributed to the type of industrial effluents. To our best knowledge, there is no battery industry in and around Taiz city. Also, few vehicles around this area were one of the reasons that reduce amounts of lead. In this study, the concentration of arsenic is higher than the recommended limit by (2006) and it was released to the atmosphere from both natural and anthropogenic sources such as volcanic activity and pesticides. The concentrations of iron (Fe)in all plant species samples were higher than permissible limit according to WHO (2006) although iron is an essential element for all plants and has many important biological roles such as photosynthesis, chloroplast development and chlorophyll synthesis(Nagajyoti et al. 2010).

Table 3.

ICP results of the plant species samples collected around Al-Buraihi sewage station

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
Ag	0.392	0.000	0.000	0.000	0.000	0.464	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.000	0.000	0.000	0.000	8.309	0.000	0.000	0.000	0.000	0.000	0.000	0.000
As	1.489	0.126	0.507	0.489	0.948	1.215	0.695	0.555	1.007	0.198	0.614	1.087
B	13.501	14.844	11.380	5.806	5.428	17.527	11.959	12.425	7.571	0.921	4.843	18.221
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Be	0.007	0.000	0.000	0.000	0.000	0.050	0.002	0.001	0.000	0.000	0.000	0.001
Cd	0.025	0.073	0.000	8.338	0.239	0.000	0.000	0.504	0.000	0.000	0.077	0.005
Co	0.000	0.006	0.000	0.000	0.696	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.020	0.057	0.000	0.000	0.034	0.070	0.030	0.000	0.000	0.000	0.035	0.023
Cu	0.000	0.000	0.000	58.767	13.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.000	0.000	121.672	221.611	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Li	0.296	0.032	0.153	0.218	0.230	0.285	0.330	0.000	0.372	0.190	0.086	0.231
Mn	0.000	64.899	0.000	16.260	70.085	7.041	0.000	0.000	0.000	0.000	26.977	0.000
Mo	1.096	3.983	0.000	0.000	0.000	4.201	0.256	0.000	1.313	0.000	0.018	0.000
Ni	0.000	0.000	0.000	2.226	7.311	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SO	0.025	0.000	0.000	0.000	0.000	0.499	0.000	0.000	0.779	0.000	0.000	0.000
Se	0.000	0.131	1.738	0.846	0.727	3.730	0.000	0.000	0.231	0.034	0.000	0.000
Sn	0.316	0.061	1.702	0.000	0.448	0.870	0.000	1.461	0.006	0.432	1.012	0.502
Zn	0.000	37.679	0.000	266.445	107.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	647.043	190.960	845.744	0.000	147.677	551.147	675.709	0.000	109.957	0.000	0.000	486.717
Mg	963.202	1345.790	1123.103	502.797	764.709	1103.787	1274.331	1410.638	0.000	0.000	583.820	1275.728
Na	2803.105	4921.312	3122.965	0.000	0.000	1279.217	3268.770	984.689	0.000	0.000	1058.000	1997.590
P	0.000	21.116	1.610	380.562	448.740	0.000	0.000	0.000	21.053	358.900	10.955	22.689

Table 4.

Descriptive statistics of the elements in plant species samples (n=12, mg/kg)

Element	**Minimum**	**Maximum**	**Mean**	**StDev**	**P-value**	**Reference**
Ag	0.000	0.46	0.071	0.17	0.000	-
As	0.126	1.49	0.74	0.41	0.063	0.10 a
Cd	0.000	8.34	0.77	2.39	0.000	0.01 a
Co	0.000	0.70	0.06	0.20	0.243	0.05 a
Cr	0.000	0.07	0.02	0.02	0.287	0.10 a
Cu	0.000	58.77	6.05	17.07	0.334	0.20 a
Fe	0.000	221.61	28.61	70.12	0.008	5.00 a
Mn	0.000	70.09	15.43	25.77	0.185	0.20 a
Mo	0.000	4.20	0.91	1.56	0.000	0.10 b
Ni	0.000	7.31	0.80	2.15	0.062	0.50 c
Pb	ND	ND	ND	ND	ND	5.00 a
Sb	0.000	0.78	0.11	0.26	0.227	-
Se	0.000	3.73	0.62	1.11	0.168	0.02 a

Sn	0.000	1.70	0.57	0.58	0.080	-
Zn	0.000	266.45	34.27	79.64	0.006	2.00 a

[a] WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater(WHO 2006)

[b] Analysis Methods for Soil, Plant, Water and Fertilizers (Alzoubi et al. 2013)

[c] Irrigation water. Yemen Standardization, Metrology & Quality Control (YSMO150/2001 2001)

Table 5.
Pearson correlation test for common parameters of Soil and plant samples collected around at Al-Buraihi sewage station

Correlations

		Ag	Al	As	B	Ba	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sc	Sn	Zn	Ca	K	Mg	Na	P
Ag	Pearson Correlation	1	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Al	Pearson Correlation	1.000**	1	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
As	Pearson Correlation	1.000**	1.000**	1	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
B	Pearson Correlation	1.000**	1.000**	1.000**	1	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ba	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cd	Pearson Correlation	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Co	Pearson Correlation	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	1	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cr	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**

Correlations

		Ag	Al	As	B	Ba	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sc	Sn	Zn	Ca	K	Mg	Na	P
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cu	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mn	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mo	Pearson Correlation	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ni	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pb	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sc	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sn	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1	1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Zn	Pearson	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1	1.000**	1.000**	1.000**	-1.000**	1.000**

Correlations

		Ag	Al	As	B	Ba	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sc	Sn	Zn	Ca	K	Mg	Na	P
	Correlation																					
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ca	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1	1.000**	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
K	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1	1.000**	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mg	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1	-1.000**	1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Na	Pearson Correlation	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1	-1.000**
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
P	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	1.000**	1.000**	-1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	1
	Sig. (2-tailed)																					
	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

** Correlation is significant at the 0.01 level (2-tailed).

8. Correlation Test

The correlation analysis between the soil samples and the plant species samples is given in Table 5. In the present work, we have attempted to understand the relationship between the soil samples and plant sample using correlation analyses for the results obtained using ICP. In statistics, the correlation test is used to determine the degree of a linear relationship between the two variables. Noteworthy that the range is between −1 to 1 in a correlation analysis. If the values obtained are nearer to 1or -1, implies that there is a strong positive linear relationship between the correlated variables, if the values are nearer to 0, indicates that there is no linear relationship between two variables. The ICP results obtained for soil samples and Plant species samples were subjected to correlation analysis. Based on the statistical results obtained, we can say that there is a strong correlation between the soil and plant samples and are significant at 0.01 level, since all the results obtained are -1 and 1. This indicates that the micronutrients, macronutrients and the heavy metals, from the wastewater used for irrigation around Al-Buraihi sewage station, has been transferred to the soil, and from soil to the plants through biomagnification.

9. Conclusion

Sampling, ICP analysis and statistical analysis of both soil and plant samples were carried out. ICP analysis revealed that almost half of the elements examined falls within the permissible limits recommended by the international standards which include both the macronutrients (K, Ca and Mg) and micronutrients (Ba, Cd, Co, Cr, Fe, Mn, Ni, Pb and Sr). Apart from these elements heavy metals such as Ag, As, B, P, Cu, Mn, Mo, Sb, Sc, Se, Sn and Zn exceeded the permissible limits recommended by the above-mentioned standards. Statistical analysis revealed that there is a significant correlation between the parameters of the soil and plant samples, signifying the possible intake of the nutrients and heavy metals by the Napier grass species. The number of heavy metals intaken by the Napier grass species demonstrates that this species can be used as a bio-indicator to determine the heavy metals present in the soil. Meanwhile, the Napier grass grown on contaminated soil should not be used as fodder for cattle since there are possibilities of the moment of these heavy metals from species to species through the process of bio-magnification.

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