EUROPEAN ACADEMIC RESEARCH
Vol. IV, Issue 3/ June 2016

ISSN 2286-4822
www.euacademic.org

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Determination of the Extent of Contamination of Sorghum by Heavy Metals in Yemen Republic

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Abstract:

This study aimed to determine the extent of contamination of sorghum grains samples by heavy metals in two areas in the Republic of Yemen collected during the period of June 2012 to August 2013, namely from Alrashdh-Dhamar area and the vicinity of Amran cement Factory in Amran area. The collected samples were digested by wet method and analyzed by ICP- Optical Emission Spectrometric technique. The results showed a contamination in both samples by the elements: zinc, lead, iron, arsenic, and nickel that exceeded the allowable limits set by Codex Alimentarius. The study showed that there is a high level of contamination by heavy metals in both sorghum samples. The heavy metals contamination is not solely due to cement industry activities but involves other pollution sources.

Key words: Heavy metal, sorghum, contamination, environment.

INTRODUCTION

Metals occur naturally in the earth's crust, and their contents in the environment can vary between different regions resulting

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in spatial variations of background concentrations. The distribution of metals in the environment is governed by the properties of the metal and influences of environmental factors. (Khlifi, R. and Hamza-Chaffai, A. 2010).

Heavy metals is the generic term for metallic elements having an atomic weight higher than 40.04 (the atomic mass of Ca) and density much greater (at least 5 times) than water. (Ming-Ho 2005).

Of the 92 naturally occurring elements, approximately 30 metals and metalloids are potentially toxic to humans, Be, B, Li, Al, Ti, V, Cr, Mn, Co, Ni, Cu, As, Se, Sr, Mo, Pd, Ag, Cd, Sn, Sb, Te, Cs, Ba, W, Pt, Au, Hg, Pb, and Bi. There are more than 20 heavy metals, but four are of particular concern to human health: lead (Pb), cadmium (Cd), mercury (Hg), and inorganic arsenic (As), according to the U.S. Agency for Toxic Substances and Disease Registry (2003). These four heavy metals are four of the top six hazards present in toxic waste sites. They are highly toxic and can cause damaging effects even at very low concentrations. They tend to accumulate in the food chain and in the body and can be stored in soft (e.g., kidney) and hard tissues (e.g., bone). Being metals, they often exist in a positively-charged form and can bind on to negatively-charged organic molecules to form complexes (Vieira, C. *et al*., 2011).

Heavy metals enter the environment by natural and anthropogenic means. Such sources include: natural weathering of the earth's crust, mining, soil erosion, industrial discharge, urban runoff, sewage effluents, and pest or disease control agents applied to plants, air pollution fallout and a number of others. (Ming-Ho 2005). Although some individuals are primarily exposed to these contaminants in the workplace, for most people the main route of exposure to these toxic elements is through the diet (food and water). The contamination chain of heavy metals almost follows a cyclic order: industry, atmosphere, soil, water, foods and human. The presences of heavy metals specially (Cd, Zn, Fe, Ni and Pb) in higher concentration are known to have adverse effect on growth of plants, animals and human health. Although toxicity and the resulting threat to human health of any contaminant are of course, a function of concentration, it is well-known that chronic exposure to heavy metals and metalloids at relatively low levels can cause adverse effects. (Agency for Toxic Substance and Disease Registry 2003), (Uneyama, C. *et al.*, 2007).

Sorghum, a grain, forage or sugar crop is among the most efficient crops in conversion of solar energy and use of water. Sorghum is known as a high-energy, drought tolerant crop. Because of its wide uses and adaptation "sorghum is one of the really indispensable crops" required for the survival of humankind. (Pinto, AP., *et al.*, 2004). Sorghum grain ranks 5th in cereals for global production. Sudan is first ranked among Arab countries of the area planted by sorghum crop that reaches about 9082.50 hectares represented 87% of the total area cultivated in the Arab World. Yemen ranked second with cultivated area of 556.11 hectares of sorghum crop. (Arab agricultural statistics year book 2009).

Sorghum is a genus with many species and subspecies, and there are several types of it including grain sorghums, grass sorghums (for pasture and hay), sweet sorghums (for syrups), and Broomcorn. (Carter, P.R. *et al.*, 2006).

The grain sorghum (*Sorghum bicolor* ssp. *Bicolor*) is the type that has been studied in this study. Because of the industrial revolution and the resulting negative effects on the environment in general and because sorghum in Yemen ranks first in terms of cultivated area for cereals, this study was selected to determine the extent of contamination of sorghum grains cultivated in the vicinity of a cement factory.

MATERIALS AND METHOD

Materials

All chemicals used were of analytical reagent grade. These include:

Hydrochloric acid, nitric acid and perchloric acid. The samples of sorghum were collected from two different areas in the Republic of Yemen; the first is Dhamar, Directorate alhaddae, isolation Al-rashdh 100 km south east of the Capital Sana'a. It is located in the largest branch of the valley Zna which flows into the famous Marib Dam story Arm torrent Al Sheba. The second is from Amran in Amran Directorate, 55 km north-west of the Capital Sana'a.

Sample collection

Sample one was collected randomly from three different regions in an environment free of rural industries and placed in plastic containers, until the processing of the sample for analysis. Sample two was collected randomly from area around the Amran Cement Factory and placed in plastic containers until they were analyzed.

Equipments

Oven (Heraeus. Function line T6- Kendro), analytical balance (Shimadzu, Sartorius-AC211P), digital hotplate (Shimadzu, MS-300), and Inductively Coupled Plasma- Optical Emission Spectrometer (ICP-OES) (Egilent, 7700x).

Preparation of samples

The samples were grinded and made into powder using grinder then kept in self -sealing polyethylene bags.

Determination of moisture content:

Moisture content of samples was determined according to AOAC (1990) method. The loss on drying was calculated as follows:

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100$$

W_1 = Original weight of sample (g).
W_2 = Weight of sample after drying (g).

Analysis of Heavy Metals:

Wet digestion method was used to digest the samples to prepare it for ICP -OES analysis. For analysis of heavy metals in plant portion of, 1.0 g dry, powdered plant sample was placed in a test tube with 5 ml of a 5:1 mixture of aqua regia (HNO_3 – HCl) and perchloric acid ($HClO_4$). The mixture was then digested at 95°C for approximately 1 hour until complete digestion. (AOAC 1990), (Lin Q. *et al.*, 2003). After digestion, the samples were left to cool and then transferred to 100-ml volumetric flasks. The test tubes used for digestion were rinsed with distilled water and the rinsing water was added to the volumetric flasks to bring the volume to 100 ml. Metal analysis was carried out using (ICP -OES) instrument.

RESULTS AND DISCUSSION

Moisture content

Moisture content in sample 1 and sample 2 was found to be 7.44% (w/w) and 8.99% (w/w) respectively. These are the normal ranges usually observed. The value of the moisture content in the samples was further used in heavy metals analysis to determine the metals concentration on dry weight bases.

Heavy Metals

Heavy metals in the collected sorghum samples were analyzed by ICP- OES instrument; the results obtained were shown in Table (1) and Figures (1, 2 and 3).

Table (1): Element concentration in samples and allowable limit in cereals according to Codex Alimentarius (1995).

Element	Conc. of element by ppm in sample one	Conc. of element by ppm in sample two	Limit toxicity of element in codex alimentarius, by ppm
As	1.870	1.766	0.2
Ba	4.045	9.83	5
Cd	<0.0652	0.1318	0.2
Cr	0.3994	1.156	1
Cu	11.55	9.49	10
Fe	79.11	81.76	15
Ni	2.143	2.787	0.1
Pb	1.587	2.160	0.2
Se	ND	ND	-----
Zn	22.86	27.67	5

The concentration of arsenic (As) in both of sample one and sample two, 1.87 and 1.77 ppm respectively, is nearly ten times higher than the limits of As recommended by Codex Alimentarius. The concentration of Fe, Ni and Zn are also very high compared to the recommended limits, especially Fe which as high as 5 folds the recommended limits, while Ni is 20 times higher and Zn is 5 times higher than the corresponding Codex Alimentarius limits. This is also true for Pb which is 10 folds higher than the specified Codex Alimentarius limits. It worth noting here that these heavy metals do not seem to originates from cement factory but from another source of contamination. The contamination by Ba in sorgum samples (1 and 2) was found to be 4.1 and 9.8ppm respectively. Comparing these values with the recommended limits, it is inferred that the presence of cement industry activity in the area has raised the concentration of Ba in the environment.

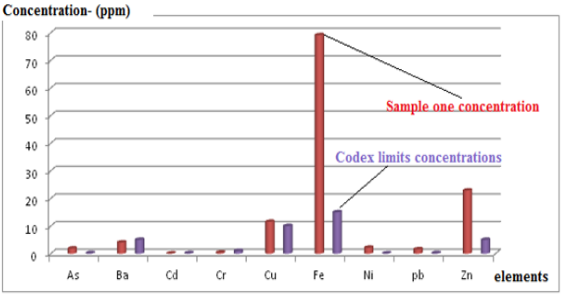

Figure 1. Comparison between heavy metals concentrations in sample one and codex limits

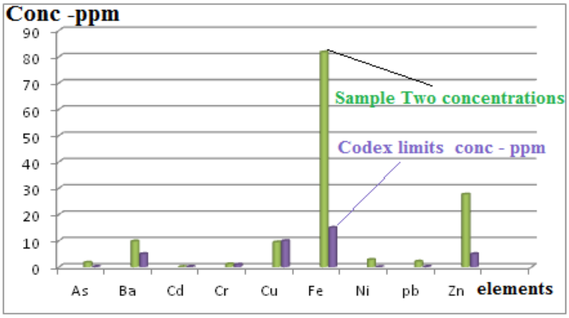

Figure 2. Comparison between heavy metals concentrations in sample two and codex limits

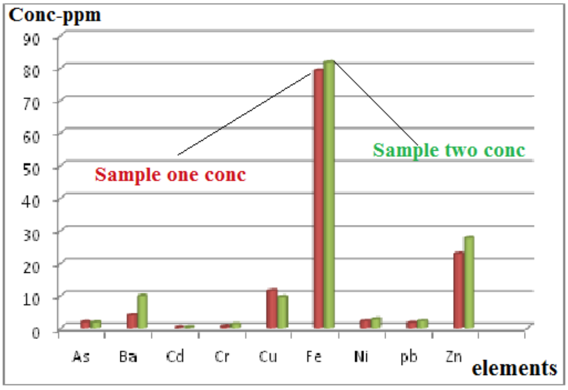

Figure 3. Comparison between heavy metals concentrations in samples one and two

First sample showed high concentration of some elements which may be due to the movement assisted with rainwater sloping to the area where the sample was cultivated, i.e in the slopes and their tributaries multiple. Add to that the indiscriminate use of pesticides to spray the Qat which is cultivated side by side with sorghum. The uptake of heavy metals (Cd, Pb and Zn) by maize, oat and sorghum plants cultivated, under field conditions, in industrially polluted soils was studied. (Murillo, J.M. *et al.*, 1999), (Abdul Ghani 2010). Sorghum plants accumulated larger heavy metal quantities compared to maize and oat plants, as the major part of heavy metals was retained by roots and a very small part was translocated to epigeous parts. Leaves of sorghum plants accumulated more As, Bi, Cd, Mn and Pb (Murillo, J.M. *et al.*, 1999).

The toxic effects on the plant growth, nitrogen content in plant parts, and protein content in seeds, exerted by two metals in combination were not additive, but rather only as severe as for the most toxic metal alone (Abdul Ghani 2010).

CONCLUSION

- The two samples tested in this study were polluted by heavy metals, but sample two which was taken from the vicinity of Amran cement factory in Amran area was more polluted than sample one and its contamination exceed the limits set in codex Alimentarius.
- Owing to their toxicity and their possible bioaccumulation, heavy metals should be subject to mandatory monitoring. Exposure measurements are essential for the protection of high risk populations and subgroups in Amran area.

Acknowledgement

One of the authors (Ahmed Hamoud Alsarem) would like to thank the Ministry of Education, Sanaa, Yemen for financial support.

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