Journal of Environmental Sciences Vol. 10, No. 2, pp. 245—251, 1998 ISSN 1001—0742

Accumulation of heavy metals in two crop seeds due to soil contamination as determined by neutron activation analysis techniques

M. F. Abdel-Sabour

Soil and Water Department, Nuclear Research Center, Cairo, Egypt

A. S. Abdel-Haleem

Hot Lab's Center, Atomic Energy Authority, Cairo, Egypt

A. Sroor, N. Abdel-Baset

Nuclear Physics Lab, Girls Faculty, Ain Shams University, Egypt

R. A. Zaghloul

Mubarak City for Scientific Research and Technology, Egypt

Abstract—Samples of two crop seeds (corn and sesame) grown on different contaminated soil sources were collected and prepared for neutron activation analysis. Soil contamination sources were organic waste compost applied to soil amendments namely, sewage sludge(Bs) and municipal solid waste (MSW) at 4%, 6% and 8% respectively. The non-destructive NAA technique was used to determine some trace elements accumulation in plant seeds.

Results revealed that increasing rate of tested organic waste resulted in dramatic increase in tested heavy metals levels in seeds(i.e., Fe, Zn, Co, Cr, Sc and Hg). Sesame seeds showed higher affinity to accumulate trace elements than corn grains in most tested elements. Moreover, MSW addition enhanced the accumulation of tested metals in seeds more than Bs compost.

Keywords: heavy metals; crop seeds; neutron activation analysis techniques.

1 Introduction

Usually, only part of the total amount of heavy metals in soil is available to plants (Page, 1981; Singh, 1984). Heavy metals and rare earth elements content of food products (i.e. cereal, oil crops, fruit *etc*.) are of great importance with respect to man's intake of such metals in his food. Crop species differ with respect to heavy metals uptake and their transport to edible tissues. The advantages of plant analysis are diminished by a number of practical limitation, including (1) element concentration in plants depend on sampling time (physiological age of the plant) and thus analytical results of plant samples collected at different stages of growth are poorly comparable, and may give misleading estimates of the element status. (2) Element contents of different plant species are seldom comparable. Great differences exist also in the element concentration between different parts of the same plant. Generally, heavy metals concentration are much lower in storage tissues such as seed, fruit, tubers or rhizomes than in leaves (Chino, 1981; Hansen, 1984; McKenna, 1990). (3) The ability of different cultivars to absorb elements may vary considerably (Randhawa, 1975). (4) Contamination is a factor which limits the usability of plant analyses. (5) At normal yield levels the available contents of elements in soils are reflected by the respective contents in plants, however, this rule is less valid in cases of restricted plant growth (enrichment factor) or in cases of vigorous growth (dilution factor). However, food crops represent an important pathway for the movement of heavy metals from soils to humans. Table 1 compares the percentage of daily intake of Fe, Mn, Zn, Cu and Cd from different food groups (Fox, 1988). As we can see in Table 1 plant food contributes to a higher extent to daily Fe, Mn, Zn, Cu and Cd intake than food of animal origin.

Table 1 Total daily intake of some heavy metals (70kg adult male) and percentage of total intake by food class (based on Fox, 1988)

Element	Total intake, mg/kg	Percentage of daily intake by food class			
		Fruit and vegetables	Grain and cereals	Dairy products	Meat fish/ poultry
Fe	10—18.8	16	52	5	20
Mn	3.61	21	55	1	1
Zn	13.2—15	11	19	20	43
Cu	1.56	30	31	5	21
Cd	0.02	40	36	10	5

In previous work the application of Bs and MSW compost to sandy soil enhanced the accumulation of heavy metals content in soil and plant (Abdel-Sabour, 1996). However, it is reported that the health risk of human exposure to plant-metal is not simply a function of metal concentration in edible plant tissues times the mass of plant food consumed (McKenna, 1990). For example, Cd bio-availability from food crops needs to be interpreted not only in terms of Cd concentrations but also other interfering elements or compounds concentration such as Zn concentration, Cd and Zn speciation in edible plant tissues.

The aim of this study is to evaluate the potential risk of heavy metals from food crops grown in soils contaminated with heavy metals.

2 Materials and methods

Corn (*Zea maize*) and sesame (*Sesamn undicum* L.) seed samples were collected from different contaminated soil plots with heavy metals due to Bs and MSW compost application at different rates namely 4%, 6% and 8%. For complete details about the filed trail (Abdel, 1994). Seed samples were dried at 105℃ until a constant weight was obtained, then ground and stored for analysis. The mineral content of ground seed samples was determined by non-destructive delayed neutron activation analysis. An approximately 0.1 g of each sample was sealed in aluminum foil in addition to blank aluminium foil as a background. Also, about 3 mg Au foil was used as a single comparator, to calculate the thermal neutron flux. The whole samples were irradiated for 48 hour at the first Egyptian reactor (ER-RR-1). The thermal neutron flux was 4.4×10^{12} n/(cm$^2\cdot$s) at the reactor core.

Using hyperpure germanium detector of resolution 1.9 keV at 1332.5 keV gamma-ray line of ^{60}Co, associated with electronic circuits contains spectroscopy amplifier coupled to program system and an on-line multichannel computer. The detector and the attached electronic were used for measuring the induced radio activities.

3 Results and discussion

Neutron activation analysis (NAA) was employed to measure Fe, Zn, Sc, Co, Cr and Hg in two plant species seeds(corn and sesame). Increasing trend of metals concentration in crop speeds was observed due to the increase in organic waste rate of application(Table 2). However, the accumulation of metals in crop seeds was always higher in case of MSW addition compared to Bs addition Figs. 1—2, for all studied elements. This may suggest that metals in case of MSW are relatively available compared with Bs treatment. Moreover, sesame seeds showed higher accumulation of heavy metals than corn grains which indicate higher affinity for sesame plant(oil crop) to accumulate heavy metals than corn (cereal crop).

Table 2 Sesame seeds and corn grains content of Fe, Zn, Co, Cr, Sc and Hg(ppm) as affected by soil contamination(source and rate)

Rate, %	Elements	Sesame seeds		Corn grains	
		Bs	MSW	Bs	MSW
4	Fe	50.2	198.7	27.1	69.2
6		147.1	277.4	29.8	122.5
8		154.2	336.6	43.6	136.5
4	Zn	55.2	45.0	35.62	61.5
6		99.5	84.5	49.6	88.5
8		111.5	121.9	60.2	136.4
4	Co	1.79	3.82	2.21	3.67
6		2.58	4.23	2.56	8.034
8		3.19	7.75	3.75	12.02
4	Cr	0.77	1.69	0.54	1.35
6		1.08	2.93	0.73	1.63
8		1.56	4.14	0.92	1.95
4	Sc	0.126	0.297	0.152	0.166
6		0.165	0.420	0.115	0.321
8		0.283	0.577	0.165	0.347
4	Hg	0.022	0.052	0.007	0.016
6		0.015	0.075	0.009	0.024
8		0.017	0.093	0.012	0.038

The sample under investigation were positioned individually at about 10 cm from the front of the detector. A set of standard gamma-ray sources such as ^{241}Am, ^{137}Cs, ^{60}Co, and ^{22}Na were used for energy calibration of the system up to 3MeV(Lederer, 1978). Using the multielement standard sources for calculating the absolute efficiency. Each sample was measured for 2 hours counting time after 24 hours cooling time.

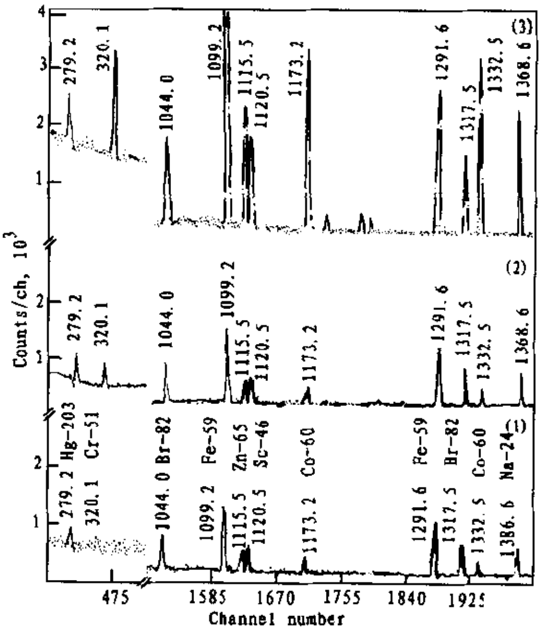

Fig. 1 Partial gamma-spectrum for sesame seeds samples
1. Normal sample; 2. higher BS treatment;
3. higher MSW treatment

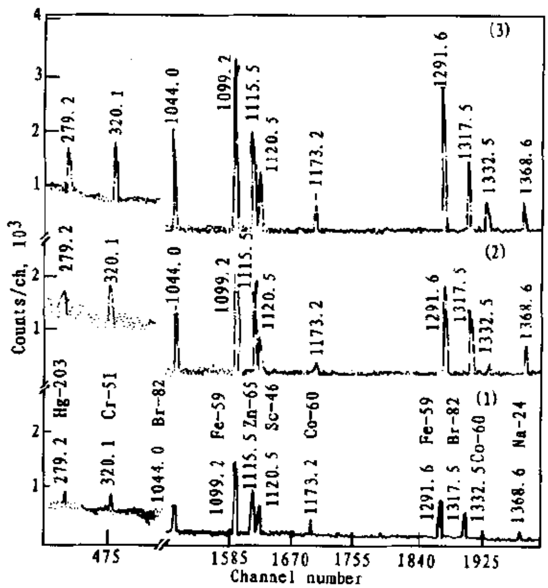

Fig. 2 Partial gamma-spectrum for corn seeds samples
1. Normal sample; 2. higher BS addition; 3. higher MSW addition

3.1 Iron

The importance of Fe in human diet is well known. Iron deficiency anaemia is a widespread health problem, particularly among children and women of child nearing age in Egypt (Asker, 1986). Iron content ranged from 50.2 to 736.6 ppm in sesame seeds and from 27.1 to 136.5 ppm in case of corn grains. These levels of iron are relatively high. However, no toxicity symptoms are reported due to high level of iron in plant food. The total intake by human was reported between 10—18.8 ppm(Fox, 1988). A linear regression relations were obtained between seeds-Fe content and organic waste rate of application as follows:

$$\text{Sesame seeds-Fe} = 17.34 + 17.26\text{Bs} - \text{rate}(R^2 = 0.829)^{**}$$

$$= 35.00 + 39.00\text{MSW} - \text{rate}(R^2 = 0.95)^{**},$$

$$\text{Corn grains-Fe} = 19.73 + 2.42\text{Bs} - \text{rate}(R^2 = 0.802)^{**}$$

$$= 19.68 + 15.08\ \text{MSW} - \text{rate}(R^2 = 0.965)^{**}.$$

3.2 Zinc

Zinc content varied due to plant species and soil treatment whereas, it ranged from 24.0 to

140.9 ppm for sesame and 5.6—136.4 ppm for corn. Zinc is extremely important to nutritional health. The recommended daily allowances for Zn has been set to a 15 mg for adult(RDA, 1979). Legumes and cereals have fair amounts of Zn but it is largely unavailable due to the presence of phytic acid and dietary fibber, which interfere with Zn absorption (Sandstead, 1968). Zinc deficiency is known in Egypt. It's major symptoms are deplayed growth and wound healing (Holden, 1979). Both tested plant seeds have a reactively high content of Zn, but not all of these amounts are available. The regression equations for Zn are as follows:

$$\text{Sesame seeds-Zn} = 24.70 + 10.90\ \text{Bs} - \text{rate}(R^2 = 0.936)^{**}$$
$$= 18.77 + 12.335\text{MSW} - \text{rate}(R^2 = 0.880)^{**},$$
$$\text{Corn grains-Zn} = 24.23 + 4.17\text{Bs} - \text{rate}(R^2 = 0.926)^{**}$$
$$= 19.74 + 13.05\text{MSW} - \text{rate}(R^2 = 0.941)^{**}.$$

3.3 Cobalt

Cobalt is apart of vitamin B_{12}. It is the vitamin B_{12} content in foods and not the Co content, that supplies human needs for this element. Cobalt content in sesame seeds ranged from 1.8—14.8 ppm, however in corn grains it was 2.2—26 ppm. It was reported that although Co is presented in a variety of food stuffs(meats and dairy, and to a less extent in cereals, grains and vegetables), the physiologically active form must be consumed(RDA, 1979).

$$\text{Sesame seeds-Co} = 0.834 + 0.286\ \text{Bs} - \text{rate}(R^2 = 0.983)^{**}$$
$$= 0.644 + 0.788\text{MSW} - \text{rate}(R^2 = 0.912)^{**},$$
$$\text{Corn grains-Co} = 1.75 + 0.196\text{Bs} - \text{rate}(R^2 = 0.734)^{**}$$
$$= 0.877 + 1.233\text{MSW} - \text{rate}(R^2 = 0.878)^{**}.$$

3.4 Chromium

Chromium enhances the activity of insulin in the metabolism of glucose activates several enzymes and may play a role in protein and lipid metabolism (RDA, 1979). The range of Cr content in sesame seeds was from 0.77—2.14 ppm and in corn grains was 0.54 to 1.95 ppm. The RDA for Cr was reported to be 0.05 = 0.2ppm(RDA, 1979).

$$\text{Sesame seeds-Cr} = 0.282 + 0.146\text{Bs} - \text{rate}(R^2 = 0.959)^{**}$$
$$= 0.161 + 0.470\text{MSW} - \text{rate}(R^2 = 0.974)^{**},$$
$$\text{Corn grains-Cr} = 0.367 + 0.063\text{Bs} - \text{rate}\ (R^2 = 0.928)^{**}$$
$$= 0.467 + 0.193\text{MSW} - \text{rate}\ (R^2 = 0.985)^{**}.$$

3.5 Scandium

Scandium levels varied from 0.036—0.277 ppm for sesame seeds and 0.115 to 0.347 ppm for corn grains. The reported range for Sc in plant foods was 0.002 to 0.1 ppm(Duke, 1970).

$$\text{Seasame seeds-Sc} = 0.001 + 0.030\text{Bs} - \text{rate}\ (R^2 = 0.959)^{**}$$
$$= 0.012 + 0.069\text{MSW} - \text{rate}(R^2 = 0.999)^{**},$$
$$\text{Corn grains-Sc} = 0.078 + 0.011\ \text{Bs} - \text{rate}(R^2 = 0.746)^{**}$$
$$= 0.059 + 0.037\text{MSW} - \text{rate}\ (R^2 = 0.941)^{*}.$$

3.6 Mercury

The distribution of Hg in plants has recently received the most study because of the Hg pathway into food chain. Therefore, most information is at present related to Hg content of plant food stuffs. The Hg contents of cereal grains seem to be fairly similar for various countries with mean values ranging from 0.9 to 21 ppb. However, grain crops from land where mercuric compound dressings of seeds were used show elevation in Hg content up to 170 ppb(Dabrowski, 1977). Our data show Hg levels between 15—93 ppb for sesame seeds and 7 to 38 ppb for corn grains. The relative high values of Hg was observed with the MSW treatment, particularly at 8% rate of application and for sesame seeds:

$$\text{Sesame seeds-Hg} = 0.012 + 0.001\text{Bs} - \text{rate}(R^2 = 0.393)^{**}$$
$$= 0.009 + 0.011\text{MSW} - \text{rate}(R^2 = 0.998)^{**},$$
$$\text{Corn grains-Hg} = 0.005 + 0.001\text{Bs} - \text{rate}(R^2 = 0.850)^{**}$$
$$= 0.004 + 0.004\text{MSW} - \text{rate}(R^2 = 0.936)^{*}.$$

The constant in the regression equations reflects soil factors(for the intercept constant A) and plant affinity to absorb metals (for the slope constant B).

4 Conclusion

The results revealed that heavy metals accumulate in the growing crops due to organic waste addition(Fig. 3). Which mean that metals could transfer from contaminated soil to plant and readily enter the food chain. Thus, the monitoring of metal levels in soil and foodstuff is essentially

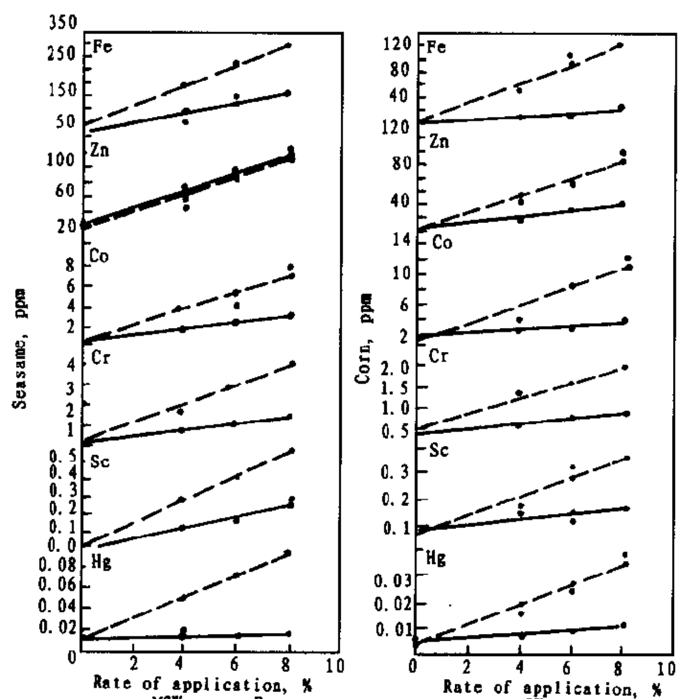

Fig. 3 Effect of organic waste addition on Fe, Zn, Co, Cr, Sc and Hg in sesame seeds and corn grains

required. The good sensitivity of NAA technique makes it a good tool for such monitory needs.

References

Abdel-Sabour M F, Egyptian J Soil Sci(in press), 1998

Abdel-Sabour M F, M A Rizk, M A Massoud. Egyptian J Soil Sci(in press), 1998

Abdel-Sabour M F, A R A G Mohamed. Final report, Project No. C-3- 10 NARP, US-AID project 263-0152, Cairo, Egypt. 1994

Asker A. Ernahrung/Nutrition, 1986, 10: 847

Chino M, Baba A. J Plant Nutr, 1981, 3: 203

Duke J A. Econ Bot, 1970, 23: 344

Dabrowski J, Poliborski M, Majchrzak J, Polak J. Proc 17th Nat Semin of the Institute of Plant Protection. Poznan. 1977. 95

Fox M R S. J Environ Qual, 1988, 17: 175

Hansen L G, Chaney R L. Reviews in Environ Toxicology(Ed. by Hodgson E). New York: Elsevier Sci Pub, 1984. 103

Holden J M, Wolfe W R, Mertz W J. Dietetic Assoc, 1979, 75: 23

Kreutler P. Nutrition in perspective. Englewood Cliffs, New Jersey, USA: Prentice-Hall Inc., 1980

McKenna I M, Chaney R L. Proc 4th intern conf Baltimore MD: Johns Hopkins University, 1990. 65

Page Al L. Inter conf heavy metals in the environment. Amsterdam: CEP Consultants, Edinburgh, 1981. 206

Randhawa N S, Takkar P N. Repe Fert News, 1975, May: 9

RDA Nat Acad of Sci. Washington DC: NRC, 1979

Sandstead H H. Nutrition Today, 1968, 3(1): 12

Singh B R, Narwal R P. J Environ Qual, 1984, 13: 344

(Received for review August 11, 1997. Accepted August 26, 1997)