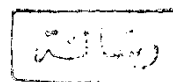


# TOXICITY OF CERTAIN HEAVY METALS

BY

SAID ABD EL-MONIEM HASSAN



A thesis submitted in partial fulfillment  
of  
the requirements for the degree of  
DOCTOR OF PHILOSOPHY

In  
Agricultural Science  
(Soils)

Department of Soil  
Faculty of Agriculture  
Ain Shams University



1994

## Approval Sheet

### TOXICITY OF CERTAIN HEAVY METALS

By

Said Abd El-Moniern Hassan

B.Sc. Soil Science, Faculty of Agriculture,  
Al-Azhar University, 1975

M.Sc. Soil Science, Faculty of Agriculture,  
Ain-Shams University, 1986

This Thesis for Ph.D. degree has been  
approved By :

Prof. Dr. M.A. Omar .....  
Prof. of Soil Science, Soil Sci. Dept.,  
Fac. of Agric., Al-Azhar Univ.

Prof. Dr. A.M. Elgala .....  
Prof. of Soil Science, Soil Sci. Dept.,  
Fac. of Agric., Ain Shams Univ.

Prof. Dr. A.I. Metwally .....  
Prof. of Soil Science, Soil Sci. Dept.,  
Fac. of Agric., Ain Shams Univ.

Date of examination : 14 / 02 / 1994



## TOXICITY OF CERTAIN HEAVY METALS

By

Said Abd El-Moniem Hassan

B.Sc. Soil Science, Faculty of Agriculture,  
Al-Azhar University, 1975

M.Sc. Soil Science, Faculty of Agriculture,  
Ain Shams University, 1986

Under the supervision of :

Prof. Dr. A.I. Metwally

Professor of Soil Science &  
Fac. of Agric., Ain Shams University

Prof. Dr. Akila Saleh Hamza

Professor of Food Science  
and Director of Central Lab.  
for Food and Feed,  
Ministry of Agriculture

Dr. H. E. Abu Hussin

Soil Department  
Fac. of Agric., Ain Shams University

### ABSTRACT

The objectives of this study were to, assess and evaluate the status of Cd and Pb in water, soil and different crops in waste water irrigated area of Bahr El-Baqar. Also to study the uptake, translocation and accumulation of these heavy metals in different plant parts of different crop plants and their effect on amino acid metabolism in addition to their genotoxic effects. The content of Cd and Pb largely varied in different crops and were highest in roots than in shoots, least in grains and pods and increased with the duration of irrigation with waste water. Cadmium adversely affected bean and spinach plants at lower concentrations in the nutrient media than Pb and spinach growth was more affected than beans specially at latter stages of growth. The accumulation of both metals was higher in bean roots and spinach shoots. Data indicate that plants whose roots can act as a barrier for heavy metal translocation tolerate higher concentrations of heavy metals in the nutrient media. Both plants accumulated such high concentrations of both Cd and Pb before growth was adversely affected. These concentrations reached 196, 76 and 60 ppm Cd and 780, 72 and 48 ppm Pb in roots, stems and leaves of beans respectively and 45 and 28 ppm Cd and 221 and 128 ppm Pb in roots and shoots in spinach.

The amino acid content (THR, SER, GLU, ALA, VAL, ILE, LEU, TYR, PHE, HIS, LYS, CYE, METH) and also true protein content of bean pods progressively decreased by increasing Cd or Pb concentrations. Aspartic acid, arginine and non-

protein nitrogen, on the other hand, increased as Cd and Pb increased in the nutrient media. Data indicated that both heavy metals adversely affected protein synthesis in plant.

Genotoxic effect of Cd and Pb in *Vicia faba* was studied by examining the chromosome behaviour in the root tip and pollen mother cells as affected by increasing Cd and Pb concentrations in the nutrient media. Generally, the percentage of various aberrations increased with increasing Cd and Pb levels in mitotic and meiotic systems progressively. More work is needed to evaluate the mutagenic effect of these heavy metals at various concentrations.

**Key words** : Cadmium, lead, *Vicia faba*, bean, *Spinacia oleracea*, spinach, uptake, accumulation, translocation, toxicity.

## ACKNOWLEDGEMENT

The author wishes to express his deep appreciation and gratitude to Prof. Dr. A.I. Metwally, Professor of Soil Science, Fac. of Agric., Ain-Shams Univ., for his supervision, fruitful discussion and valuable help offered during writting of this manuscript.

My sincere thanks to Prof. Dr. M.S. Foda, Professor of Soil Science, Fac. of Agric., Ain-Shams Univ. for suggesting the problem, encouragement and valuable criticism throughout the laboratorial and field work.

My special thanks to Prof. Dr. Akila S. Hamza, The Director of the Central Lab. for food and Feed for her cooperation, encouragement and providing all facilities necessary for the completion of this work.

I am grateful also to Dr. H.E. Abu-Hussin, Soil Department, Fac. of Agric., Ain-Shams Univ. for his help throughout the preparation of this manuscript.

Thanks are also due to Dr. M.Z. Attalah, Researcher of Genetics, Agric., Researcher Centre, Alex. for his help in mutagenic analysis and preparation of this part in manuscript.

## CONTENTS

	Page
1. INTRODUCTION .....	1
2. REVIEW OF LITERATURE .....	4
2.1. The presence of Cd and Pb .....	4
2.2. Absorption and Translocation of Cd and Pb in plant .....	16
2.3. Toxicity and biological effects of Cd and Pb .....	24
2.4. Genotoxic effect of Cd and Pb .....	29
3. MATERIALS AND METHODS .....	33
3.1. Uptake, translocation and accumultation of Cd and Pb in bean and spinach plants as affected by heavy metal concentration in sand culture .....	33
3.1.2. Effect of Cd or Pb in nutrient solu- tion on the amino acid, true protein and non protein nitrogen content of bean pods .....	34
3.1.3. Genotoxiceffect of Cd and Pb .....	35
3.2. Assessment of Cd and Pb levels in soil, irrigation water and growing plants in Bahr El-Baqar area .....	37
3.3. Accumulation and distribution of Cd and Pb in bean and spinach plants cultivated in two selected locations of Bahr El-Baqar area..	39

	Page
3.4. Method of analysis :	
3.4.1. Soil analysis .....	39
3.4.2. Plant analysis .....	40
3.4.3. Water analysis .....	44
4 RESULTS AND DISCUSSION .....	45
4.1. Uptake, translocation and accumulation of Cd and Pb in bean and spinach plants as affected by heavy metal concentration in sand culture .....	45
4.1.1. Response of bean plants to increasing Cd and Pb concentrations in nutrient solution .....	45
4.1.1.1. Plant growth .....	45
4.1.1.2. Contents of Cd and Pb in bean plant.	54
4.1.1.3. Effect of Cd or Pb in nutrient solution on the amino acid, true protein and non protein nitrogen content of bean pods .....	65
4.1.1.4. Genotoxic effect of Cd and Pb .....	73
4.1.2. Response of spinach plants to increa- sing Cd or Pb concentration in the nutrient solution .....	82
4.1.2.1. Plant Growth .....	82
4.1.2.2. Contents of Cd and Pb in plant tissues .....	90
4.1.3. Effect of both Cd and Pb on spinach .....	103





## LIST OF TABLES

Table No.	Title	Page
1	Effect of increasing Cd concentration in the nutrient solution on dry matter (g/pot) of bean plants of successive growth stages (28, 56, 91 and 150 days after planting) .....	46
2	Effect of increasing Pb concentration in the nutrient solution on dry matter (g/pot) of bean plants at successive growth stages (28, 56, 91 and 150 days after planting) .....	50
3	Effect of increasing Cd concentration in the nutrient solution on the Cd status in the different bean plant parts at successive growth stages (28, 56, 91 and 150 days after planting) .....	55
4	Accumulation index of Cd in bean plant as affected by Cd concentration in nutrient solution .....	58
5	The amount of Cd in different part of bean as percent of the total Cd uptake..	59

Table No.	Title	Page
6	Effect of increasing Pb concentration in nutrient solution on the Pb status in the different bean plant parts at successive growth stages (28, 56, 91 and 150 days after planting) .....	61
7	Accumulation index of Pb in bean plant parts as affected by Pb concentration in nutrient solution .....	63
8	The amount of Pb in different part of bean as a percent of the total Pb uptake	64
9	Effect of Cd and Pb supplied in nutrient solution on amino acid percentage in bean pods .....	66
10	Effect of Cd and Pb supplied in nutrient solution on true protein and non protein nitrogen percentage in bean pods .....	70
11	Effect of Cd and Pb in nutrient media on amino acids contents in bean pods as a percentage of the control treatment ....	72

Table No.	Title	Page
12	Effect of Cd and Pb concentrations in nutrient media on true protein and non-protein nitrogen in bean as percentage of control .....	72
13	Mitotic indices and percentage of aberrant metaplasms induced after treatment with Cadmium and Lead .....	74
14	Frequencies of meiotic abnormalities induced by different concentrations of Cd and Pb in Vicia faba .....	78
15	Effect of increasing Cd in the nutrient solution on spinach dry matter (g/pot) at successive growth stages (28 and 63 days after planting) .....	83
16	Relative growth reduction (% of control) in spinach plants as affected by increasing Cd concentration in nutrient solution .....	85

Table No.	Title	Page
17	Effect of increasing Pb concentrations in the nutrient solution on spinach dry matter (g/pot) at successive growth stages (28 and 63 days after planting) ..	87
18	Relative growth reduction (% of control) in spinach plants as affected by increasing Pb concentration in nutrient solution .....	89
19	Effect of increasing Cd concentration in nutrient solution on the Cd status in different spinach plant parts at successive growth stages (28 and 63 days after planting) .....	91
20	Cadmium content of different plant parts as percent of the whole plant content...	94
21	Accumulation index of Cd in spinach plant parts as affected by Cd concentration in nutrient solution .....	96

Table No.	Title	Page
22	Effect of increasing Pb concentration in nutrient solution on the Pb status in the different spinach plant parts at successive growth stages (28 and 63 days after planting) .....	97
23	Lead content of different plant parts as percent of the whole plant content .....	100
24	Accumulation index of Pb in spinach plant parts as affected by Pb application in nutrient solution .....	101
25	Effect of Cd and Pb in nutrient solution on spinach dry matter (g/pot) at successive growth stages (28, 63 after planting) .....	104
26	Relative growth reduction (% of control) in spinach plants as affected by increasing Cd and Pb concentration in nutrient solution .....	105

Table No.	Title	Page
27	Effect of Cd and Pb applied in nutrient solution on the Cd, Pb content and accumulation index (AI) in different spinach plant parts of successive growth stage .....	107
28	Some physical and chemical properties of studied soils .....	110
29	Extractable Cd and Pb (ppm) from studied soils .....	113
30	Chemical composition of Bahr El-Baqar drain water during cultivation period...	115
31	Concentration of Cd and Pb (ppm) in studied plants growing in Bahr El-Baqar area .....	117
32	Bean dry matter (kg/plot) in the two selected locations of Bahr El-Baqar, irrigated with drainage water for 10 and 40 years .....	122