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# IMPROVEMENT OF CERTAIN HEAVY ELEMENTS STATUS IN SALT-AFFECTED SOIL IRRIGATED WITH LOW QUALITY WATER

**Elsharawy, M.A.O.; T.A.Taha; M.A.M. Mostafa and Shaimaa H. Abd Elrahman**

*Soils Dept., Fac. of Agric., Ain Shams Univ., Shoubra El-Kheima, Cairo, Egypt.*

## ABSTRACT

Wastewater, mostly without pretreatment, has been used for irrigation in some locations such as Bahr El-Baqar drain area in El-Hosinia plain, Sharkia Governorate. A survey study including wastewater, soil and plant was carried out in El-Hosinia area to identify such problem. Moreover, certain amendments i.e. gypsum, byproduct rich in Ca from citric acid company (BCC) and citric acid, were applied to contaminated studied soil columns experiment to assess their effects on the distribution of Fe and Mn among the different soil fractions as well as the bioavailability of certain heavy elements, consequently their contents in cotton seeds.

The obtained results showed that Bahr El-Baqar drain water was contaminated with Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd which were higher than exceeded the permissible limits, while roots of alfalfa and rice plants grown on such soil contained Fe and Mn,as well as plants shoots contained only Fe , above the normal range.

Soil Fe fractions were in the following order: residual fraction> reducible bound> organically bound> carbonate fraction> exchangeable Fe, but Mn fractions were in the following order: reducible bound> residual fraction> carbonate fraction> organically bound> exchangeable Mn. The applied treatments increased the downward movement of Fe and Mn as indicated by increasing their concentrations with increasing soil depth and this point out to the possibility of reducing such heavy elements concentration at plant root zone. Gypsum amendment was superior in reducing the chemically available Fe and Mn followed by byproduct (BCC). Heavy elements content in seeds of cotton plants cultivated in soil columns were within the sufficient range.

**Keywords:** Heavy elements – Salt affected soils – Low quality water – Improvement - Industrial byproducts – Fractionation – Cotton plants.

# INTRODUCTION

Soils high in salt and/or sodium may limit crop yields. Salt-affected soils may contain an excess of water-soluble salts (saline soils), exchangeable sodium (sodic soils) or both an excess of salts and exchangeable sodium (saline-sodic soils). Heavy element is one of the pollutants which cause severe threats to humans and the environment. There are three sources of water pollution with heavy element; industrial emission, wastewater and solid waste. Wastewater, mostly without pretreatments, has been used in some locations such as Bahr El-Baqar area for production of grains and vegetables for human and cattle consumption. Wastewater of different drains in Egypt contains considerable concentrations of many heavy elements. El-Sayed (2007) reported that water of Zeifta drain may be considered not safe for usage as regards to Ni and Cd but safe as regards to Pb and Zn. Values of both EC and pH, opposite to organic matter content, were high at long distances from source of pollution, and this may explain the obtained trend of heavy elements distribution in the studied area. Perez *et al*. (2003) found that reuse of poorly purified and industrial waters in semi-arid areas lead to progressive desertification. Eid (1984) found that the content of Fe, Mn, Zn, Cu, Pb, Cd, Ni and Co in Egyptian soils irrigated with sewage effluent increased with time. Mosalem (1997) revealed that increasing irrigation period of sewage effluent at El-Gabal El-Asfar farm has increased both extractable and total Fe, Zn, Mn, Cu, Ni, Pb, Co and Cd elements in soil.

Thus, the aim of this study is to apply certain traditional and non-traditional amendments to El-Hosinia soil (salt-affected soil) through equilibration column experiment to decrease the harmful effect of heavy metals on soil chemical properties as well as to improve the seeds of cotton plants under wastewater irrigation

# MATERIALS AND METHODS

To improve the status of certain heavy elements of such soil, the following experiment was conducted. PVC columns, 60 cm long and 20 cm internal diameter, were packed with the surface soil sample (0-20 cm) of El-Hosinia plain, Sharkia Governorate, clay soil, *Vertic Torrifluvents*. Some physical and chemical characteristics of the studied soil are given in table (1). According to salinity and alkalinity criteria outlined by Richards (1954), soil is classified as saline sodic soil. Such soil was irrigated for long years with water of Bahr El-Baqar drain which causes severe salinity problem and moderate alkalinity hazard according to Ayers and Westcot (1985). The soil was packed to a height of 55 cm of the columns which were arranged in a randomized block design with three replicates for each treatment. Four treatments were applied as follows:

- Control (soil without amendments).
- Gypsum, 16.12 $g.kg^{-1}$ soil (equal to 21.3 ton/fed./20 cm).
- Byproduct from citric acid company rich in Ca, 16.12 $g.kg^{-1}$ soil (equal to 21.3 ton/fed./20 cm).
- Citric acid, at a rate of 0.98 $g.kg^{-1}$ soil. The amounts of citric acid were dissolved in irrigation water giving a solution of pH 6.5.

Characteristics of the used amendments are shown in Abd Elrahman (2008). The amounts of applied amendments were the recommended rates to reduce the ESP of soil to below 15%.

**Table 1: Some physical and chemical characteristics of the studied soil (0-20 cm).**

| Characteristic | Value |
|---|---|
| **Particle size distribution, %** | |
| Clay | 50.7 |
| Silt | 36.6 |
| Sand | 13.0 |
| Texture class | Clay |
| $CaCO_3$, % | 6.10 |
| OM, % | 1.51 |
| pH (paste) | 7.36 |
| $EC_e$, $dS.m^{-1}$ | 7.34 |
| SAR | 21.8 |
| ESP, % | 31.0 |

Firstly, gypsum and byproduct treatments were applied through mixing with soil in the columns. Moisture content of treated soil columns was kept at field capacity. Then 45 days later, citric acid treatments were added to the other soil columns through irrigation water. Soil columns were leached with excess amounts of irrigation water. The washed columns were cultivated with cotton (*Gossypium hirsutum* L., c.v Giza 85) in summer season.

Soil samples were collected after plant harvest (185 days from sowing) at depth of 0 to 15, 15 to 30 and 30 to 55 cm. The collected samples were air dried, crushed, sieved through a 2 mm sieve and stored for their chemical characteristics determination.

Plant samples (seeds) were collected at the same time of soil sampling, prepared and kept for heavy elements determination.

Routine analysis of the tested soil was determined according to the standards methods published by Richards (1954) and Jackson (1958). Total heavy elements in soil was determined by digesting 1.0g of dried samples with hydrofluoric/ perchloric acids and heavy elements concentrations were detected by atomic absorption spectrophotometer (Jackson, 1958). Chemically available heavy elements were extracted with DTPA solution from soils according to Lindsay and Norvell (1978). Thereafter, heavy elements in the extracts were determined using atomic absorption spectrophotometer. After cotton harvesting, soil samples were taken from different depths. Such samples were subjected to sequential extraction according to Tessier *et al.* (1979) to estimate the different forms of Fe and Mn. Total heavy elements in plant were determined by digestion solutions ($H_2SO_4/H_2O_2$) and were analyzed for heavy elements by atomic absorption spectrophotometer (Jackson, 1958).

# RESULTS AND DISCUSSION

**Heavy elements content of water, soil and some growing plants:**

Data in table (2) reveal that Bahr El-Baqar drain, mainly, was contaminated with heavy elements, i.e. Fe, Mn, Cu, Ni, Co and Cd, which were higher than the permissible levels, but Zn and Pb only were below the permissible limits according to the criteria of water quality for irrigation purposes published by Ayers and Westcot (1985). The increase in concentration of different heavy elements in Bahr El-Baqar drain water may be due to that Bahr El-Baqar is the main drain in the Nile Delta which collects most of wastewater i.e.

industrial, sewage effluent and agricultural wastewater from Cairo, Qalubia and Sharkia Governorates.

**Table 2: Heavy elements content of the collected current water samples, mg.L$^{-1}$**

| Month | Fe | Mn | Zn | Cu | Pb | Ni | Co | Cd |
|---|---|---|---|---|---|---|---|---|
| **Bahr El-Baqar drain water** | | | | | | | | |
| Jul., 2004 | 7.31 | 0.84 | 0.67 | 0.44 | 0.81 | 0.29 | 0.10 | 0.05 |
| Oct., 2004 | 7.01 | 0.78 | 0.63 | 0.41 | 0.76 | 0.28 | 0.09 | 0.04 |
| Jan., 2005 | 5.63 | 0.71 | 0.53 | 0.34 | 0.68 | 0.24 | 0.06 | 0.03 |
| Apr., 2005 | 6.22 | 0.73 | 0.58 | 0.39 | 0.73 | 0.26 | 0.08 | 0.04 |
| **Mean** | **6.54** | **0.77** | **0.60** | **0.40** | **0.75** | **0.27** | **0.08** | **0.04** |
| Nile water# | 0.78 | 0.13 | 0.11 | 0.06 | 0.04 | 0.01 | n.d.* | n.d. |

* n.d.= not detected.
\# Average of four seasons.

| | Fe | Mn | Zn | Cu | Pb | Ni | Co | Cd |
|---|---|---|---|---|---|---|---|---|
| | 5 | 0.2 | 2 | 0.2 | 5 | 0.2 | 0.05 | 0.01 |

-Recommended maximum concentration (mg.L$^{-1}$) in irrigation water, cited from Ayers and Westcot (1985).

Data listed in table (3) show the total and DTPA–extractable amounts of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd in surface layer of the studied soils which irrigated continuously with Bahr El-Baqar wastewater. Increasing total amounts of heavy elements in the soil could be mainly due to repeating irrigation with wastewater. Values of total heavy elements in the studied soils were compared with their levels considered by European Union, reported by Kabata-Pendias and Pendias (1992) and Alloway (1995) for maximum acceptable total heavy elements concentration in agricultural soils for plant growth, animal and human consumption. The present data show that Mn and Cu concentrations in the soil irrigated with Bahr El-Baqar drain exceeded the permissible limits. However, the ranges of DTPA-extractable Fe, Zn, and Cu in soils in term of mg.kg$^{-1}$ are considered adequate. These ranges were reported by Rose and Wang (1998) as 15-40, 5-30 and 0.5-1.5, respectively. The maximum background levels of Zn, Cu, Pb, Ni and Cd extracted by DTPA in term of mg.kg$^{-1}$, were given by Logan and Miller (1982) as 11.2, 7.7, 7.9, 2.6 and 3.6, respectively.

**Table 3. Total and DTPA-extractable heavy elements of the studied soil (mg.kg$^{-1}$).**

| Fe | | Mn | | Zn | | Cu | |
|---|---|---|---|---|---|---|---|
| Total | Ext. | Total | Ext. | Total | Ext. | Total | Ext. |
| 49708 | 34.2 | 1500 | 41.5 | 209 | 11 | 98.3 | 10.4 |
| - | **>4.5#** | - | **>1#** | **150-300*** | **>1#** | **50-140*** | **>1#** |
| - | - | **1500-3000**** | - | **300-400**** | **11.2##** | **60-125**** | **7.7##** |

**Table 3: Continued**

| Pb | | Ni | | Co | | Cd | |
|---|---|---|---|---|---|---|---|
| Total | Ext. | Total | Ext. | Total | Ext. | Total | Ext. |
| 89.2 | 2.34 | 49.3 | 1.36 | 19 | 0.84 | 2.77 | 0.2 |
| **50-300*** | - | **30-75*** | - | - | - | **1.0-3.0*** | - |
| **100-400**** | **7.9##** | **100**** | **2.6##** | **25-50**** | - | **3.0-8.0**** | **3.6##** |

* Maximum total contents (mg.kg$^{-1}$), European Union, Alloway (1995).

**Maximum total contents (mg.kg$^{-1}$), Kabata-Pendias and Pendias (1992), levels considered as hytotoxic.

\# Adequate levels extracted by DTPA (mg.kg$^{-1}$), cited from McKenzie (1992).

\## Maximum background levels extracted by DTPA (mg.kg$^{-1}$), cited from Logan and Miller (1982).

Plant species and varieties differ widely in their abilities to adsorb, accumulate and tolerate heavy elements. Contents of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd in root and shoot of alfalfa, in winter season, and rice, in summer season, are given in table (4). The obtained results coincide with the pervious findings for soil and irrigation water. Roots and shoots of alfalfa and rice plants contained Fe above the normal range as compared with the limits of Jones (1967), while Mn concentration was above the normal range only in plants roots as compared with the limits of Kabata-Pendias and Pendias (1992).

**Table 4: Concentrations of heavy elements in different parts of some plants collected from soils irrigated with drainage water or Nile water.**

| Plant sample | Fe | Mn | Zn | Cu | Pb | Ni | Co | Cd |
|---|---|---|---|---|---|---|---|---|
| | mg.kg$^{-1}$ | | | | | | | |
| | Irrigation with Bahr El-Baqar drain | | | | | | | |
| **Alfalfa** | | | | | | | | |
| Root | 1440 | 339 | 50 | 13.8 | 3.00 | 1.90 | 0.90 | 0.11 |
| Shoot | 836 | 191 | 36 | 7.80 | 1.15 | 0.74 | 0.36 | 0.03 |
| **Rice** | | | | | | | | |
| Root | 1458 | 343 | 55 | 15.7 | 4.1 | 2.03 | 0.95 | 0.14 |
| Shoot | 848 | 196 | 41 | 9.00 | 2.4 | 0.93 | 0.41 | 0.05 |
| | Irrigation with Nile water | | | | | | | |
| **Alfalfa** | | | | | | | | |
| Root | 124 | 46 | 12 | 0.30 | 0.28 | 0.08 | 0.04 | 0.00 |
| Shoot | 67.5 | 23 | 7.5 | 0.17 | 0.09 | 0.05 | 0.01 | 0.00 |
| **Rice** | | | | | | | | |
| Root | 185 | 50 | 13 | 0.50 | 0.33 | 0.10 | 0.05 | 0.01 |
| Shoot | 89 | 27 | 9.0 | 0.28 | 0.15 | 0.08 | 0.02 | 0.00 |
| Normal range,mg.kg$^{-1}$ | 50 - 250* | 30 - 300** | 27 - 150** | 5 - 30** | 5 - 10** | 0.1 - 5** | 0.02 - 1** | 0.05 - 0.2** |
| Contaminated,mg.kg$^{-1}$ | - | 400 - 1000** | 100 - 400** | 20 - 100** | 30 - 300** | 10 - 100** | 15 - 50** | 5 - 30** |

According to *Jones (1967) and **Kabata-Pendias and Pendias (1992).

**Improvement of Fe and Mn status in the studied soil:**

Data of the previously mentioned survey study indicated that Fe and Mn were the two elements that occurred in amounts near or higher than the permissible limits. Consequently, chemical properties, particularly Fe and Mn behaviour and distribution in the different soil fractions were selected to be improved using certain amendments.

**1-Distribution of iron:**

Data in table (5) show the distribution of different forms of Fe throughout soil columns treated with certain amendments under irrigation with Bahr El-Baqar drain water, after harvesting cotton plants. Generally, the amended or not amended soil contained Fe forms as follows: RES> OXD> ORG> CAB> EXC.

The residual fraction, reducible bound Fe and carbonate fraction were higher in gypsum followed by, BCC and citric acid treatments. The organically bound, the exchangeable Fe and chemically available Fe values were higher in citric acid, followed by BCC and gypsum treatments. Distribution of Fe among the different fractions in the untreated soil (control) showed that the residual fraction is the prevalent form in soil which represented about 96.8% of the sum of Fe fractions. This could be due to the high soil pH values by leading element to be precipitated.

**Table 5: Effect of different amendments on Fe and Mn fractions in Bahr El-Baqar soil irrigated with Bahr El-Baqar drain water after harvesting cotton plants.**

| Amendment | Depth, | Fe fractions, $mg.kg^{-1}$ | | | | | | | Mn fractions, mg.kg-1 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cm | EXC## | CAB | OXD | ORG | RES | Sum | DTPA-Fe | EXC | CAB | OXD | ORG | RES | Sum | DTPA-Mn |
| Control | 0-15 | 27.3 | 21.7 | 1093 | 410 | 47300 | 48845 | 33.0 | 41.0 | 71.0 | 896 | 69.7 | 198 | 1276 | 49.7 |
| | 15-30 | 29.3 | 23.0 | 1096 | 413 | 47340 | 48894 | 37.0 | 42.0 | 73.0 | 901 | 71 | 201 | 1288 | 50.7 |
| | 30-60 | 30.7 | 25.0 | 1095 | 414 | 47433 | 48991 | 38.0 | 43.3 | 76.0 | 904 | 73.3 | 203 | 1300 | 52.0 |
| **Mean** | | **29.1** | **23.2** | **1095** | **412** | **47358** | **48910** | **36.0** | **42.1** | **73.3** | **900** | **71.3** | **201** | **1288** | **50.8** |
| Gypsum | 0-15 | 21.0 | 20.0 | 994 | 530 | 46533 | 48094 | 26.8 | 32.0 | 65.0 | 819 | 91 | 153 | 1160 | 36.0 |
| | 15-30 | 21.7 | 23.0 | 997 | 534 | 46567 | 48137 | 27.1 | 33.3 | 67.0 | 822 | 93 | 154 | 1169 | 38.0 |
| | 30-60 | 24.0 | 23.7 | 1001 | 532 | 46613 | 48187 | 29.9 | 36.9 | 69.7 | 823 | 96.3 | 156 | 1182 | 40.7 |
| **Mean** | | **22.2** | **22.2** | **997** | **532** | **46571** | **48139** | **27.9** | **34.1** | **67.2** | **821** | **93.4** | **154** | **1170** | **38.2** |
| BCC# | 0-15 | 22.0 | 20.0 | 897 | 586 | 46037 | 47557 | 27.3 | 34.0 | 64.3 | 809 | 100 | 139 | 1146 | 39.0 |
| | 15-30 | 22.7 | 21.3 | 901 | 587 | 46077 | 47604 | 28.0 | 34.7 | 67.0 | 812 | 103 | 137 | 1154 | 39.5 |
| | 30-60 | 25.8 | 23.3 | 903 | 590 | 46093 | 47627 | 32.0 | 37.6 | 68.0 | 813 | 105 | 141 | 1165 | 43.3 |
| **Mean** | | **23.5** | **21.5** | **900** | **588** | **46069** | **47596** | **29.1** | **35.4** | **66.4** | **811** | **103** | **139** | **1155** | **40.6** |
| Citric acid | 0-15 | 24.3 | 19.7 | 837 | 596 | 45567 | 47038 | 30.0 | 33.8 | 59.8 | 756 | 116 | 125 | 1090 | 40.7 |
| | 15-30 | 26.7 | 21.0 | 841 | 598 | 45640 | 47121 | 33.4 | 37.6 | 61.1 | 758 | 117 | 128 | 1101 | 46.4 |
| | 30-60 | 28.9 | 21.7 | 845 | 597 | 45667 | 47153 | 38.6 | 43.8 | 63.1 | 761 | 120 | 131 | 1118 | 48.4 |
| **Mean** | | **26.6** | **20.8** | **841** | **597** | **45625** | **47104** | **34.0** | **38.4** | **61.3** | **758** | **118** | **128** | **1103** | **45.2** |
| $L.S.D_{0.05}$ | | **1.40** | **1.11** | **10.9** | **10.4** | **41.1** | **40.6** | **2.81** | **2.00** | **1.08** | **10.1** | **11.0** | **12.6** | **13.9** | **1.85** |

# Byproduct from citric acid company, rich in Ca.

## EXC, CAB, OXD, ORG and RES means exchangeable, carbonate, reducible bound,organically bound and residual fractions, respectively.

The obtained results agree with the findings of El-Gendi et al. (1997) and Abou Zied (1999). Reducible bound Fe was the second dominant fraction; on average the reducible bound Fe of the studied soil represented 2.24%, while the organically bound Fe represented 0.84% of the sum, followed by Fe associated with carbonates which represented 0.047% of the sum. The exchangeable fraction of Fe has the lowest values among the operationally defined ones. It amounted to 0.045% of the sum of the extracted Fe fractions. The DTPA-Fe which represents the chemically available Fe showed similar trend to that of EXC-Fe. Generally, all Fe fractions and DTPA extractable Fe in all treatments were increased with increasing soil depth to show the downward movement by increasing solubility and leachability.

**2- Distribution of manganese:**

On average, percent of total Mn associated with different fractions in the studied untreated soil was in the following order: Fe-Mn oxide (69.9%)> residual (15.6%)> carbonate (5.69%)> organic (5.53%)> exchangeable (3.27%), respectively (show table, 5). Zhang *et al.* (1997) found that the distribution of various forms of Mn was significantly influenced by the soil pH and organic matter content. Mn was present predominantly as organically bound forms at pH $< 6.5$ or as Mn oxide and amorphous associated forms at pH $> 6.5$. On the other hand, data reveal that under effect of certain amendments percent of total Mn associated with different fractions in the studied soil was in the following order: Fe-Mn oxide> residual> organic> carbonate> exchangeable. This explained the highest amount of Mn which correlated with the organic fraction under the effect of these amendments, especially for citric acid treatment. The obtained data showed also that chemically available Mn showed similar trend with exchangeable Mn. However, the untreated or treated tested soil contained available Mn higher than the critical level (3 to 5 $mg.kg^{-1}$) according to Sillanpaa (1982).

Gypsum amendment was superior in reducing the chemically available Fe and Mn from the studied soil, followed by byproduct (BCC).

**Dry weight and heavy elements content of cotton plants:**

Data in table (6) show the yield of dry weight and weight of 1000 seeds of cotton plants cultivated in Bahr El-Baqar soil as affected by different amendments, under irrigation with tap water or Bahr El-Baqar drain water. It is clear that cotton dry weight as well as heavy elements content values were significantly lower in case of irrigation with tap water compared with drain water irrigation. It could be also noticed that addition of such amendments to the contaminated soil under investigation improved, relatively their chemical properties which in turn promotes plants growth, improves general plant vigour and encourages their yields. Under irrigation with Bahr El-Baqar drain water the dry weight and weight of 1000 seeds showed increases recording (17.8 and 18.5%) > (12.7 and 13.3%) > (10.6 and 9.4%) over the control for BCC, gypsum and citric acid treatments, respectively.

Seeds, as an important part of cotton crop, were taken to study their content of trace elements after harvesting cotton plants. Application of such amendments under irrigation with Bahr El-Baqar drain water were significantly decreased the seeds content of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd compared to control treatment, especially for gypsum. It recorded 29.1, 24.8, 26.4, 31.5, 57.1, 47.1, 52.9 and 60.0% less than the control treatment, respectively. While, BCC recorded 20.6, 15.0, 19.3, 19.5, 40.7, 24.3, 41.2 and 40.0% less than the control, respectively. Whereas, citric acid treatment decreased the studied heavy elements in cotton seeds by about 8.50, 6.70, 11.8, 14.1, 19.8, 12.9, 26.5 and 20.0% less than the control, respectively, recording the lowest decreases compared with other treatments. This could be due to the role of organic acids such as citric acid in reducing soil pH and increasing solubility of such elements. Also, soluble organic complexes of certain heavy elements could play an important role in getting such elements more available to plant, Barness and Chen (1991).

In general, trace elements concentrations in seeds of cotton plants reflect the amounts of the chemically available heavy elements present in the cultivated soil, which in turn is highly affected by both the source of contamination and kind of amendment applied to this soil. The obtained data was compared with the potentially toxic levels of trace elements in plants according to Jones (1967) and Kabata-Pendias and Pendias (1992). Heavy elements content in seeds of cotton plants at harvest period were within the sufficient range under irrigation with Bahr El-Baqar drain water. Several authors have shown that trace elements tend to accumulate in roots of plants rather than shoots, flowers and seeds, among them Zhang and Wang (1991), Wang *et al.* (1997) and Abou El-Naga *et al.* (1999). But continues irrigation with drainage water of Bahr El-Baqar could increase heavy elements content in the different parts of plants, especially for those cultivated in heavy clay soils. Therefore, these soils can be planted with woody trees for human and animal safety.

**Table 6: Dry weight, weight of 1000 seeds and trace elements concentrations of seeds of cotton plants cultivated in Bahr El-Baqar soil as affected by different amendments under irrigation with tap water or Bahr El-Baqar drain water.**

| Amendment | Dry weight of whole plant, g/column | Weight of 1000 seeds,g | Fe | Mn | Zn | Cu | Pb | Ni | Co | Cd |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg.kg$^{-1}$ | | | | | | | |
| **Irrigation with tap water** | | | | | | | | | | |
| Control | 93.7 | 92.1 | 148 | 107 | 30.1 | 7.94 | 0.60 | 0.37 | 0.19 | 0.03 |
| Gypsum | 102 | 100 | 109 | 68.5 | 24.0 | 5.68 | 0.24 | 0.20 | 0.12 | 0.01 |
| BCC# | 108 | 103 | 123 | 80.6 | 25.7 | 5.81 | 0.30 | 0.27 | 0.14 | 0.01 |
| Citric acid | 99.6 | 96.8 | 139 | 92.0 | 27.9 | 6.12 | 0.40 | 0.31 | 0.16 | 0.02 |
| **L.S.D$_{0.05}$** | **3.28** | **2.07** | **6.59** | **5.45** | **1.13** | **0.12** | **0.07** | **0.03** | **0.02** | **0.01** |
| **Irrigation with Bahr El-Baqar drain water** | | | | | | | | | | |
| Control | 84.9 | 79.8 | 165 | 120 | 34.8 | 8.61 | 1.00 | 0.70 | 0.34 | 0.05 |
| Gypsum | 95.7 | 90.4 | 117 | 90.3 | 25.6 | 5.90 | 0.49 | 0.37 | 0.16 | 0.02 |
| BCC# | 100 | 94.6 | 131 | 102 | 28.1 | 6.93 | 0.64 | 0.53 | 0.20 | 0.03 |
| Citric acid | 93.9 | 87.3 | 151 | 112 | 30.7 | 7.40 | 0.73 | 0.61 | 0.25 | 0.04 |
| **L.S.D$_{0.05}$** | **2.91** | **2.10** | **6.22** | **4.79** | **1.69** | **0.17** | **0.08** | **0.07** | **0.03** | **0.01** |

# Byproduct from citric acid company, rich in Ca.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Normal range, mg.kg$^{-1}$ | - | - | 50 - 250* | 30 - 300** | 27 - 150** | 5 - 30** | 5 - 10** | 0.1 - 5** | 0.02 - 1** | 0.05 - 0.2** |
| Contaminated, mg.kg$^{-1}$ | - | - | - | 400 - 1000** | 100 - 400** | 20 - 100** | 30 - 300** | 10 - 100** | 15 - 50** | 5 - 30** |

According to *Jones (1967) and **Kabata-Pendias and Pendias (1992)

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# تحسين حالة بعض العناصر الثقيلة فى أرض متأثرة بالأملاح تروى بمياه منخفضة الجودة

**محمد على عثمان الشعراوى- طايع عبد اللطيف طه - محمد أحمد محمود مصطفى - شيماء حسن عبد الرحمن**

قسم الأراضي- كلية الزراعة- جامعة عين شمس- شبرا الخيمة- القاهرة- مصر

تستخدم المياه الناتجة عن الصرف - وفى الغالب بدون معالجة - فى رى بعض الأماكن مثل منطقة مصرف بحر البقر بالحسينية التابعة لمحافظة الشرقية. ولتحديد أبعاد المشكلة الناجمة خاصة فيما يتعلق بمستويات العناصر الثقيلة تم تحليل عينات من مياه الرى، التربة وبعض النباتات المنزرعه، ثم بعد ذلك أجريت تجربة أعمدة تربة لدراسة تأثير بعض المصلحات على حالة وتوزيع العناصر الثقيلة فى التربة وكذلك محتوى نبات القطن من تلك العناصر، وتتلخص أهم النتائج المتحصل عليها فى الأتي:

تحتوى مياه مصرف بحر البقر على تركيزات من عناصر الحديد، المنجنيز، النحاس، النيكل، الكوبلت والكادميوم أعلى من المستويات المسموح بها فى مياه الرى، وتعدت تركيزات المنجنيز والنحاس فى التربة الحدود المسموح بها، أما بالنسبة للنباتات النامية فى تلك المنطقة فقد احتوت جذور البرسيم والأرز على تركيزات من الحديد والمنجنيز وكذلك المجموع الخضرى لتلك النباتات على الحديد أعلى من التركيزات المسموح بها فى كلا النباتين.

أوضحت دراسة صور الحديد فى التربة أن العنصر يتوزع فى مكونات التربة كالأتي: الصورة المتبقية> المؤكسدة> المرتبطة عضوياً> المرتبطة بالكربونات> المتبادلة، بينما صور المنجنيز كانت تتوزع كالأتي: الصورة المؤكسدة> المتبقية> المرتبطة بالكربونات> المرتبطة عضوياً> المتبادلة. كما أدت إضافة المصلحات المستخدمة فى تجربة أعمدة التربة إلى زيادة حركة الحديد والمنجنيز إلى طبقات التربة السفلى وهذا يشير الى امكانية خفض تركيز العناصر الثقيلة فى منطقة انتشار الجذور، وكان التأثير الأكبر لمعاملة الجبس يتبعها معاملة مخلف مصنع حمض الستريك (BCC) . كانت تركيزات العناصر الثقيلة تحت الدراسة فى بذور نبات القطن المزروع فى أعمدة التربة تقع فى الحدود الكافية.