Solid Earth Discuss., doi:10.5194/se-2015-34, 2016
Manuscript under review for journal Solid Earth
Published: 8 February 2016

Solid Earth
Discussions
Open Access

Effect of polluted water on soil, sediments and plant contamination by heavy metals in El-Mahla El-Kobra, Egypt

E. Mahmoud[1] **and A. M. Ghoneim**[2,3]

[1]Soil and Water Sciences Dept., Faculty of Agriculture at Tanta, Tanta University, Tanta, Egypt
[2]Soil Science Department, College of Food and Agricultural Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia
[3]Agricultural Research Center, Field Crops Research Institute, Rice Research and Training Center, Sakha, 33717, Kafr El-Sheikh, Egypt

Received: 24 March 2015 – Accepted: 25 March 2015 – Published: 8 February 2016

Correspondence to: E. Mahmoud (esawy.rezk@agr.tanta.edu.eg)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

Abstract

The discharge of untreated wastewater in drains Zefta and No. 5 is becoming a problem for many farmers in El-Mahla El-Kobra area, Egypt. The discharging water contains high levels of contaminants considered hazardous to the ecosystem. Some plants, soil, water, and sediment samples were collected from El-Mahla El-Kobra area to evaluate the contamination by heavy metals. The results showed that the heavy metals, pH, sodium adsorption ratio (SAR), BOD and COD in the water of drains Zefta and No. 5 exceeded permissible limits for irrigation. In rice and maize plants grown in soils irrigated by water from Zefta and No. 5 drains, the bioaccumulation factors for Cd, Pb, Zn, Cu and Mn were higher than 1.0. The heavy metals of irrigated soils from drains Zefta and No. 5 exceeded the upper limit of background heavy metals. In this study, the mean contaminant factor values of the drain No. 5 sediments revealed that Zn, Mn, Cu, Cd, Pb and Ni > 6, indicating very high contamination, which receive a huge amount of metallic pollution due to the direct discharge of wastewater from the urban and industrial area. The high bioaccumulation coefficients of *Cynodon dactylon Phragmites australis* and *Typha domingensis* growing in Zefta drain. These species can be considered as hyperaccumulators for, decontamination of polluted water. Thus, the wastewater in El-Mahla El-Kobra area must be treated before discharge in drains (Zefta and No. 5) and remediation of polluted soils from heavy metals.

1 Introduction

Environmental contamination of heavy metals has been increased in last decades. Heavy metals have recently received more attention of researchers all over the world, and this is due to their pernicious effects on living organism such as plants, animals. Industrial wastewater contains high levels of heavy metals, dyes and organic contaminants. Industrial pollution is particularly dangerous, because it may contaminate soils, waters, crops and groundwater with heavy metals. Industrial processes produce

SED

doi:10.5194/se-2015-34

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

wastewater that contains heavy metal contaminants (Aslam et al., 2004). There is an increase in the heavy metal contents when soil irrigated with wastewater (Mapanda et al., 2005). Heavy metals in effluents are poorly soluble in water, and may bioaccumulate in crops, causing damage to plants when reach and under certain conditions become toxic to human and animals fed on these metal-enriched plants (Stephenson and Sheldon, 1996). Heavy metals persist in soil which then leaches down into the groundwater and may induce enhanced antioxidant enzymatic activities in plants or become adsorbed with solid soil particles (Iannelli et al., 2002). Heavy metals are subjected to bioaccumulation and risk to human health when moved to the food chain (Kelly et al., 1996). Cd uptake by carrot roots was about five times more than the regulatory limits for men, eight times more for women, and 12 times more for children. The results indicating, carrots grown in contaminated soils by Cd have the potential to cause toxicological problems in men, women, and young children (Roy and McDonald, 2013). High levels of Cd in soil was identified as causing itai-itai disease in Toyama Prefecture, Japan, however, soil solution levels similarly high in Cd do not seem to cause health problems for people living in Shipham, England (Morgan, 2013). For the Cu-contaminated agricultural soils with tomato (*Solanum lycopersicum* L.) assayed, these values would range between 32.9 and 1696.5 $mg\,kg^{-1}$, depending on soil properties (Sacristán et al., 2015). Accumulation of toxic heavy metals in plant living cells results in various deficiencies, reduction of cell activities and inhibition of plant growth (Kabir et al., 2008; Farooqi et al., 2009). They also sultriness chlorosis, reduced water and nutrient uptake; affect enzymatic action by exchanging metals ions with metalo-enzymes, damage root tips and the enzymes (Agarwal, 1999; Sanità di Toppi and Gabbrielli, 1999). Phytoremediation of both heavy metals and organic chemicals has received attention (Tu et al., 2002; Cho et al., 2013; Ye et al., 2014), as well as human exposures to contaminates obtained by plants through soils and passed up the food chain (Khan et al., 2008; Zhuang et al., 2009; Roy and McDonald, 2013).

Heavy metal pollution is persistent, covert and irreversible (Wang et al., 2011). This ~~kind of~~ pollution not only degrades the quality of the food crops, atmosphere, and water bodies, but also threatens the health and well-being of human and animals beings by way of the food chain (Nabulo et al., 2010; Dong et al., 2011). Excessive intake of the Pb to human body can damage the nervous, skeletal, endocrine, enzymatic, circulatory, and immune systems (Zhang et al., 2012). The chronic effects of Cd consist of lung cancer, pulmonary adenocarcinomas, prostatic proliferative lesions, kidney dysfunction, bone fractures and hypertension (Żukowska and Biziuk, 2008). Brevik and Sauer, 2015) recognized that soils influence (1) food availability and quality (food security), (2) human contact with various chemicals, and (3) human contact with various pathogens.

In El-Mahla El-Kobra, the dominant sources of heavy metal pollution are wastewater irrigation, manure and sediment applications for metallic ores. El-Mahla El-Kobra area is density populated and contains 183 industrial factories such as textile, food, oil, and other industries. The quantity of industrial and municipal wastewater is around 243 500 $m^3 day^{-1}$ (107 500 $m^3 day^{-1}$ of municipal sewage and 136 000 $m^3 day^{-1}$ of industrial wastewater), which discharge into Zefta drain (flow, 354 240 $m^3 day^{-1}$) and drain No. 5 (flow, 265 248 $m^3 day^{-1}$) without treatment except 63 627 $m^3 day^{-1}$ of municipal wastewater can be treated in Dawakhlia plant. At present time, large amount of untreated industrial wastewater is disposed into surface bodies (Saleemi, 1993). In developing countries, untreated city effluent is generally disposed onto agricultural lands to establish urban cultivation around big cities (Hernandez et al., 1991; Qadir et al., 1999). In the periphery of big cities and areas with unavailability of natural surface drains, farmers use sewage water and drainage water for crop production as it is not costly (Lone and Rizwan, 1997).

The objectives of this study were to evaluate the contamination of soils and drainage water and bottom sediments of polluted drains by heavy metals in El-Mahla El-Kobra, Egypt.

SED
doi:10.5194/se-2015-34

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◀◀ ▶▶
◀ ▶
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

2 Materials and methods

2.1 Site description, samples and analysis

Seventy represented soil surface (0–30 cm) in summer 2012 were collected from cultivated lands of El-Mahla El-Kobra, Gharbia Governorate, Egypt which are irrigated with drainage water from drains No. 5 and Zefta, and Fifteen samples which are irrigated from Baher El Mlah water. In this study, the soil had been continuously irrigated with drainage water from drain No. 5 for a period of above 10 years. El-Mahla El-Kobra area is located at 30°34′ N latitude, 30°45′ E longitude. The soil is classified as a vertic torrifluvents. The soil temperature regime of the studied area could be defined as thermic and soil moisture regime as torric according to Salwa et al. (2013). The soil samples were air-dried and ground to pass through 2 mm screen for chemical analysis. The soils, pH was determined in saturated soil paste extract (Richards, 1954). Calcium and magnesium were determined titrimetrically using versenate (Jackson, 1973). Sodium was determined using flame photometer (Richards, 1954). Total carbonate was determined using the calcimeter as $CaCO_3$ percent according to Loeppert and Suarez (1996). The total heavy metals (Cd, Pb and Zn) were measured by the atomic absorption spectrophotometer after digestion the soil samples with concentrated HNO_3 and $HClO_4$ acids (Page, 1982). Samples of rice and maize plants (age 65 days in summer 2012) that are grown in the studied soils, and other three plant species (*Cynodon dactylon*, *Phragmites australis* and *Typha domingensis*) which are grown in drain Zefta were also collected at different times. The plant samples were dried in oven at 75 °C for 72 h. The total heavy metals were measured by the atomic absorption spectrophotometer after digestion the plant samples with concentrated H_2SO_4 and H_2O_2 (Chapman and Pratt, 1961).

The bioconcentration factor (BF) of each metal in plants was calculated by dividing the total content in plant by the total content in soil (Brooks, 1998).

In addition, seventeen water samples were collected from drains No. 5 and Zefta at different times (March 2012 to March 2013) at about 20 cm below water surface and chemically analyzed for pH, EC, SAR, BOD_5, COD and heavy metals (APHA, 2005).

The bioaccumulation coefficients of each metal in aquatic plants were calculated by dividing the total content in aquatic plants by the concentration in water.

Contaminant factor (Cf) for soil is the ratio obtained by dividing the concentration of each metal in the sediment by the background values (Håkanson, 1980).

$$\text{Cf} = C_{\text{Heavy metal}}/C_{\text{Background}}$$

According to Håkanson (1980): the values of Cf < 1 indicates low contamination; 1 < Cf < 3 is moderate contamination; 3 < Cf < 6 is considerable contamination; and Cf > 6 is very high contamination.

3 Results and discussion

3.1 The effect of polluted water on plant and soil contamination

Heavy metal contents were higher in rice and maize shoots grown in the around soil of Zefta drain than the same crops in soil of No. 5 drain (Fig. 1). This was due to the high total heavy metal contents in that soils (Table 1).The maize shoot contains more Fe, Cd, Mn and Pb than rice shoot, and this may be attributed to planting rice under the flooded conditions. Under the flooded conditions, Fe, Cd, Mn and Pb could be precipitate as FeS_2, CdS, MnS and PbS, respectively due to the reducing conditions. Heavy metals content of the plants exceeded the defined limits by Kabata – Pendias and Pendias (1992) and above those acceptable for elemental composition of uncontaminated plant tissue. Alloway (1990) reported that in angiosperms, uncontaminated plant tissue contains 0.64, 2.4, 160 and 14 mg kg^{-1} for Cd, Pb, Zn and Cu, respectively. It is clear from (Fig. 1 and Table 2) the higher concentrations of Cd in rice and maize plants than

SED
doi:10.5194/se-2015-34

E. Mahmoud and A. M. Ghoneim

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◀| |▶
◀ ▶
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

other metals compared with the maximum limits according to Kabata-Pendias and Pendias (1992). Li et al. (1994) found that plants absorb Cd more readily than other metals and often reaches levels that are hazardous to human healthy before any stress symptoms appear. Chitdeshwari et al. (2002) reported that used of sewage water increased the uptake of heavy metals including Cd and Cr in *Amaranthus* crop. Phosphate fertilizers as sources for cadmium when used in fertilized of rice and maize plants in this area. Phosphate fertilizers were even cases of 200 mg Cd kg^{-1}. (Nziguheba and Smolders, 2008).

The ranges of pH, EC and heavy metal contents in soil samples irrigated by water from Zefta drain, drain No. 5, and Baher El Mlah as compared to upper limit of background, are shown in (Table 1). The soils irrigated by drainage polluted water from Zefta drain and drain No. 5 induces increase of soil pH with comparison to soils irrigated from Baher El Mlah (fresh water). Similar results were noticed by Gupta et al. (2010) and Saffari and Saffari (2013) who reported that after irrigation with different dilution of sewage water, pH increased significantly. The reason for increasing soil pH attributed due to high pH in Zefta and No. 5 drains (Table 3), the soils irrigated by water from Zefta and No. 5 drains affect significantly the EC (Table 3). Indeed, in comparison to soils with irrigated from Baher El Mlah, EC is greater with irrigated by water from Zefta drain and drain No. 5. These results were in agreement with several authors like (Mollahoseini, 2013; Khaskhoussy et al., 2013). According to this increase in EC for soil irrigated with wastewater compared with soil irrigated with fresh water. Our investigation was in agreement with the previous works obtained by Kiziloglu et al. (2008) and Rana et al. (2010) who reported that irrigation with sewage water increased soil salinity, exchangeable Na, K, Ca, Mg and plant available phosphorus.

In general, the concentrations of heavy metals in soils irrigated from Zefta drain and drain No. 5 was exceeded the upper limit of background total heavy metals (Chen et al., 1992). Mn, Cd and Ni contents in soils at Zefta drain were higher than these in soils at drain No. 5 which is due to high concentration of heavy metals in Zefta drain water (Table 3). The level of heavy metals of soils irrigated from Zefta and No. 5

were higher than there of the around soils of Baher El Mlah drains. Similar results were found by Chen et al. (1992) who found that high levels of heavy metals in soils, which are irrigated from polluted water by industrial wastewater. These results coincide with those of, who found that irrigating (El-Gendi et al., 1997) sandy soil in the Abou-Rawash area with drainage water increased total Cu, Zn and Fe, which reached 125, 170 and 5 times that of the virgin soil one in the same area.

3.2 Bioconcentration factors (BF)

The BF values in the rice and maize plants at the harvesting stage are shown in (Table 2). In rice and maize grown in soils irrigated by water from Zefta and No. 5 drains, the BF for Cd, Pb, Zn, Cu and Mn were higher than 1.0. This indicates that concentrations of Cd, Pb, Cu and Mn were high bioconcentration in studied plants. Fe was an exception because, it's BF was lower than one, indicating low bioconcentration in studied plants. The BF for Cd and Pb were higher than 5.23 ± 1.6. The BF for Zn and Cu of rice were higher than maize plants grown in the same soils irrigated by water from Zefta and No. 5 drains. These concentrations were attributed to due to using Zn fertilizer as $ZnSO_4$ in rice planting. In general, BF was reported to decrease with increasing soil metal concentration (Zhao et al., 2010), and values lower than 0.2 are considered normal when plants are grown on polluted soils (McGrath and Zhao, 2003). The differences in the BF are depending on the metal and the plant types. The high BF appears for Cd, indicating good metal accumulation in rice and maize plants for Cd. The large difference between the BF in rice and maize plants may be a result of the metal-binding capacity to roots (Singh and Agrawal, 2007), available metals, interactions between of physico-chemical parameters and the plant types grown in soils (Bose and Bhattacharyya, 2008).

SED
doi:10.5194/se-2015-34

3.3 Quality of drainage water

Concentrations of BOD and COD ranged from 442 and 978 mg L^{-1} to 632 and 2445 mg L^{-1} in Zefta drain, while the BOD and COD concentrations ranged from 540 and 882 mg L^{-1} to 723 and 2301 mg L^{-1} in drain No. 5, respectively (Table 3). This water would be classified as high strength (Metcalf and Eddy, 2003). These results were in agreement with (Pescond, 1992) who reported that physico-chemical properties like total TSS, BOD and COD showed higher values in untreated sewage water compared to groundwater. The BOD/COD ratio in Zefta drain and drain No. 5 ranged from 0.25 and 0.31 to 0.45 and 0.61, respectively. With a BOD/COD ratio is below 0.5, the wastewater contains some toxic components such as dyes and heavy metals (Linsley et al., 1992).

The average value of pH in Zefta drain, drain No. 5 and Baher El Mlah was 12.2, 9.8 and 7.2, respectively. The high pH in Zefta drain and drain No. 5 was probably due to use of sodium hydroxide and silica in industrial processes. The average of total dissolved solids (TDS) was 1016 mg L^{-1} in drain No. 5, 1130 mg L^{-1} in Zefta drain and 334 mg L^{-1} in Baher El Mlah. The ~~sodium considered adsorption ratios~~ (SAR) in waters of drain Zefta and drain No. 5 were above 12, which it considered potential for aggregate slaking, soil swelling, and clay dispersion, and thus reduction in hydraulic conductivity (Mace and Amrhein, 2001). The heavy metals in the two drains were higher than in water of Baher El Mlah which could be attributed to discharge of industrial wastewater into the two drains without treatment. The level of heavy metals exceeded the criteria limits for irrigation water (FAO, 2010; E.C.S, 1992). Similar results were reported by Matloub and Mehana (1998) shows that sewage has often high ~~values of~~ temperature, pH, hardness, alkalinity, chemical oxygen demand, total soluble salts, nitrates, nitrites and cations like sodium, potassium, calcium and magnesium. Chitdeshwari et al. (2002) reported that increased levels of sewage water increased the uptake of heavy metals including Cd and Cr in *Amaranthus* crop.

SED
doi:10.5194/se-2015-34

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◂◂ | ▸▸
◂ | ▸
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

3.4 Heavy metal concentrations in sediments

The high heavy metal concentrations in sediments of drain No. 5 (Table 4) would be attributed to high pH in water which can form ions of insoluble precipitates. Heavy metals may be also mainly bound to humic substance in sediments and settling in the drain (Lasheen et al., 1981). The measured concentrations of heavy metals are higher than US EPA's toxicity reference value (US EPA, 1999). Similar finding were obtained by Thuy et al. (2007) found that heavy metals in sediments of five canals received untreated industrial wastewater were exceeded the US EPA toxicity reference value. The partitioning of heavy metals between sediment and water can be expressed as distribution coefficients (Kd) value ($l\,kg^{-1}$). Kd values of sediment samples were the highest for Zn, Cd, and Mn, and lowest for Pb, Cu and Ni. The high Kd, indicates that the sorption of metals by sediments was strong (Salomons and Forstner, 1980). Kd is found to be sensitive to low pH and redox conditions (Stephenson et al., 1995). Heavy metals may be released from settling sediments under hypoxic or acidic conditions (Stephenson et al., 1995). Sediments are both carriers and potential sources of contaminants in aquatic system and these materials also affect groundwater quality and agricultural products when disposed on land.

In this study, the mean Cf values of the drain No. 5 sediments revealed that Zn, Mn, Cu, Cd, Pb and Ni > 6, indicating very high contamination, which receive a huge amount of metallic pollution due to the direct discharge of wastewater from the urban and industrial area.

3.5 Bioaccumulation coefficients of aquatic plants

The bioaccumulation of metals in plants of *Cynodon dactylon*, *Phragmites australis* and *Typha domingensis* grown in Zefta drain are shown in (Fig. 2). The bioaccumulation coefficients of metals in *Cynodon dactylon* were higher than in *Phragmites australis* and *Typha domingensis*. As results these plant species can be considered as hyperaccumulators, and used for decontamination of polluted waters. The use of plants for de-

SED
doi:10.5194/se-2015-34

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◀| |▶
◀ ▶
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

contamination of polluted waters has been described as rhizofiltration (Brooks, 1998). Thus, the three species would be useful for bioremediation of waterways and periodically in a particular area. Bonanno (2013) showed that *Phragmites australis* and *Typha domingensis* species may be used as biomonitors of trace element contamination in sediment. Overall, *T. domingensis* and *P. australis* showed a greater capacity of bioaccumulation as well as a greater efficiency of element removal than *A. donax*. In particular, *T. domingensis* and *P. australis* may be used for Hg phytostabilization, the former acted also as a hyperaccumulator for trace elements phytoextraction and phytostabilization. In contaminated wetlands, the presence of *T. domingensis* and *P. australis* may increase the general retention of trace elements, thus, their introduction is recommended for possible actions of phytoremediation and biomonitoring. Wafaa and Al-Taisan (2009) demonstrated that *Phragmites australis* and *Tamarix aphllya* species are significant as vegetation filter and for cleaning the soils from contamination with heavy metals by phytoextraction. Antioxidant thiolic compounds were probably involved in the mechanisms used by *P. australis* to alleviate metal toxicity. As *P. australis* is considered suitable for phytostabilising metal-contaminated sediments, understanding its tolerance mechanisms to toxic metals is important to optimize the conditions for applying this plant in phytoremediation procedures (Rocha et al., 2014).

4 Conclusions

Delta drains receive high concentrations of organic and inorganic pollutants from industrial, domestic as well as diffuse agricultural wastewater. High priority should be given to Zefta and No. 5 drains sites which receiving high loads of pollutants. This was confirmed by the lower water quality and polluted soils especially by heavy metals in the El-Mahla El-Kobra area. So, the industrial and municipal wastewater sources in El-Mahla El-Kobra area must be treated before discharge in drains (Zefta and No. 5) and remediation of polluted soils from heavy metals.

SED
doi:10.5194/se-2015-34

E. Mahmoud and A. M. Ghoneim

Acknowledgements. We acknowledge Tanta University, Governorate of Tanta, Egypt for funding and support in realizing this work. Authors wish to thank College of Food and Agricultural Research Center and Deanship of Scientific Research, King Saud University, Saudi Arabia, for supporting this work.

References

Agarwal, S. K.: Studies on the effects of the auto exhaust emission on the Mitraguna patriflora, Master thesis, MDS University, Ajmer, India, 1999.

Alloway, B. J.: Heavy Metals in Soils, John Wiley and Sons, Inc., New York, ISBN 0470215984, 1990.

APHA, AWWA, and WEF: Standard Methods for the Examination of Water and Wastewater, XX edn., American Public Health Association, Washington, DC, 2005.

Aslam, M. M., Baig, M. A., Hassan, I., Qazi, I. A., Malik, M., and Saeed, H.: Textile waste watercharacterization and reduction of its COD and BOD by oxidation. Electron. J. Environ. Agric. Food Chem., 3, 804–811, 2004.

Bonanno, G.: Comparative performance of trace element bioaccumulation and biomonitoring in the plant species *Typha domingensis*, *Phragmites australis* and *Arundo donax*, Ecotox. Environ. Safe., 97, 124–130, 2013.

Bose, S. and Bhattacharyya, A. K.: Heavy metal accumulation in wheat plant grown in soil amended with industrial sludge, Chemosphere, 70, 1264–1272, 2008.

Brevik, E. C. and Sauer, T. J.: The past, present, and future of soils and human health studies, Soil, 1, 35–46, 2015.

Brooks, R.: Plants that hyperaccumulate heavy metals: their role in hytoremediation, microbiology, archaeology, mineral exploration and phytomining, CAB International, London, UK, 380 pp., ISBN: 0-85199-236-6, 1998.

Chapman, H. D. and Pratt, P. F.: Methods of Analysis for Soils, Plant and Water, Chapt. 2, Univ. of California, Division of Agric. Sci., USA, 56–64, 1961.

Chitdeshwari, T., Savithri, P., and Mahimai Raja, S.: Effect of sewage bio-solids compost on biomass yield of Amaranths and heavy metal availability, J. Indian Soc. Soil Sci., 50, 480–484, 2002.

Chen, Z. S., Lee, D. Y., Wong, D., and Wang, Y.: Effect of various treatments on the uptake of Cd from polluted soils by vegetable crops, in: Proceedings of 3rd Work Shop of Soil Pollution and Prevention, National Chuny-Hsing University Taiwan, ROC, 277–292, 1992.

Cho, C., Park, S., and Sung, K.: Subsurface and plant contamination during natural attenuation and phytoremediation of silt loam contaminated with chlorinated organic compounds, Vadose Zone J., 12, doi:10.2136/vzj2012.0081, 2013.

Dong, J., Yang, Q. W., Sun, L. N., Zeng, Q., Liu, S. J., and Pan, J.: Assessing the concentration and potential dietary risk of heavy metals in vegetables at a Pb/Zn mine site, China, Environ Earth Sci., 64, 1317–21, 2011.

Dumontet, S., Levesque, M., and Mathur, S.: Limited downward migration of pollutant metals (Cu, Zn, Ni and Pb) in acidic virgin peat soil near a smelter, Water Air Soil Poll., 49, 329–342, 1990.

E.C.S. (Egyptian Chemical Standards): Protection of the Nile River and Water Stream from Pollution, low No. 48/1992, Ministry of Irrigation, Cairo, Egypt, 1992.

FAO: The wealth of waste: the economics of wastewater use in agriculture, in: FAO Water Report No. 35, Water Development and Management Unit, Food and Agriculture Organization of the United Nations, ISBN: 978-92-5-106578-5, 2010.

Farooqi, Z. R., Iqbal, M. Z., Kabir, M., and Shafiq, M.: Toxic effects of lead and cadmium on germination and seedling growth of *Albezia lebbeck* (L.) Benth, Pak. J. Bot., 41, 27–33. 2009.

Jackson, M. L.: Soil Chemical Analysis, Constable and Company Ltd., London, 1973.

Gupta, S., Satpati, S., Nayek, S., and Garai, D.: Effect of wastewater irrigation on vegetables in relation to bioaccumulation of heavy metals and biochemical changes, Environ. Monit. Assess., 165, 169–177, 2010.

El-Gendi, S. A., Badawy, S. H., and Helal, M. I.: Mobility of some heavy metal nutrients in sandy soils irrigated with sewage effluent, J. Agric. Sci Mansoura Univ., 22, 3535–3552, 1997.

Iannelli, M. A., Pietrini, F., Flore, L., Petrilli, L., and Massacci, A.: Antioxidant response to cadmium in *Phragmites australis* plants, Plant Physiol Biochem., 40, 977–982, 2002.

Håkanson, L.: Ecological risk index for aquatic pollution control: sediment logical approach, Water Res., 14, 975–1001, 1980.

Hernandez, T., Moreno, J., and Costa, F.: Influence of sewage sludge application on crop yields and heavy metal availability, Soil Sci. Plant Nutr., 37, 201–210, 1991.

SED

doi:10.5194/se-2015-34

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

Kabata-Pendias, A. and Pendias: Trace Elements in Soils and Plants, CRC Press, Boca Raton, FL, 1992.
Kabir, M., Iqbal, M. Z., and Farooqi, Z. A.: Reduction in germination and seedling growth of *Thespesia populnea* L. caused by lead and cadmium treatments, Pak. J. Bot., 40, 2419–2426, 2008.
Kelly, J., Thornton, I., and Simpson, P. R.: Urban geochemistry: a study of influence of anthropogenic activity on heavy metal content of soils in traditionally industrial and non-industrial areas of Britain, Appl. Geochem., 11, 363–370, 1996.
Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z., and Zhu, Y. G.: Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China, Environ. Pollut., 152, 686–692, 2008.
Khaskhoussy, K., Hachicha, M., Kahlaoui, B., Messoudi-Nefzi, B., Rejeb, A., Jouzdan, O., and Arselan, A.: Effect of treated wastewater on soil and corn crop in the Tunisian area, J. Appl. Sci. Res., 9, 132–140, 2013.
Kiziloglu, F., Turanb, M., Sahina, U., Kuslua, Y., and Dursunc, A.: Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica olerecea* L. var. *botrytis*) and red cabbage (*Brassica olerecea* L. var. *rubra*) grown on calcareous soil in Turkey, Agric Water Man., 95, 716–724, 2008.
Lasheen, M. R., Abd EL-Shafy, H., and Ashmawy, A. M.: Selected metals in river water, Bull Nat. Res. Cent. Egypt, 6, 1981.
Li, G.-C., Haw-Tarn, L., and Chi-Sen, L.: Uptake of heavy metals by plants in Taiwan, Paper from conference title: Biogeochemistry of trace elements, Environ. Geochem. Hlth., 2, 153–160, 1994.
Linsley, R. K., Joseph, B., Franzini, D. L., and Freyberg, G. T.: Water Resources Engineering, fourth edn., McGraw-Hill, Inc., New York, 1992.
Loeppert, R. H. and Suarez, D. L.: Carbonate and gypsum, in: Methods of Soil Analysis, Part 3, SSSA Book Ser. 5, edited by: Sparks, D. L. et al., SSSA, Madison, WI, 437–474, 1996.
Lone, M. I. and Rizwan, M.: Evolution of industrial effluents for irrigation and their effect on soil and chemical properties, in: Proc. NSMTCC 97 Environment Pollution, Islamabad, Pakistan, 269–280, 1997.
Mace, J. E. and Amrhein, C.: Leaching and reclamation of a soil irrigated with moderate SAR waters, Soil Sci. Soc. Am. J., 65, 199–204, 2001.

SED
doi:10.5194/se-2015-34

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◀| |▶
◀ ▶
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

Mapanda, F., Mangwayanaa, E. N., Nyamangaraa, J., and Giller, K. E.: The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe, Agr. Ecosyst. Environ., 107, 151–165, 2005.

Matloub, M. A. and Mehana, T. A.: Utilization of treated sewage effluent for reclaiming a salt-affected soil, Egypt J. Appl. Sci., 13, 298–316. 1998.

Metcalf and Eddy (Eds.): Wastewater Engineering: Treatment, Disposal and Reuse, 4th Edition, McGraw-Hill, Inc., New York, 2003.

Mollahoseini, H.: Long term effects of municipal wastewater irrigation on some properties of a semiarid region soil of Iran, Intern. J. of Agro. and Plant Pro., 4, 1023–1028, 2013.

Morgan, R.: Soil, heavy metals, and human health, in: Soils and Human Health, edited by: Brevik, E. C. and Burgess, L. C., CRC Press, Boca Raton, FL, USA, 59–82, 2013.

Nabulo, G., Young, S. D., and Black, C. R.: Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils, Sci. Total Environ., 408, 5338–5351, 2010.

Nziguheba, G. and Smolders, A.: Inputs of trace elements in agricultural soils via phosphate fertilizers in European countries, Sci. Total Environ., 390, 53–57, 2008.

Page, M. A. (ed.).: Methods of Soil Analysis, Part 2, Academic Press, New York, 1982.

Pescod, M. B.: Wastewater treatment and use in agriculture, Bull FAO 47: 125, Rome, Italy, 1992.

Qadir, M., Ghafoor, A., Murtaza, G., Sadiq, M., and Rasheed, M. K.: Copper concentration in city effluent irrigated soils and vegetables, Pak. J. Soil Sci., 17, 97–102, 1999.

Rana, L., Dhankhar, R., and Chhikara, S.: Soil characteristics affected by long term application of sewage wastewater, Int. J. Environ. Res., 4, 513–518, 2010.

Richards, R. L.: Diagnosis and improvement of saline and alkali soils, USDA Agriculture Handbook, No. 60, US Gov. Printing Office, Washington, 1954.

Rocha, A. S., Marisa, R., Almeidab, M., Clara, P., Bastoa, M., and Teresa, S. D.: Antioxidant response of *Phragmites australis* to Cu and Cd contamination, Ecotox. Environ. Safe., 109, 152–160, 2014.

Roy, M. and McDonald, L. M.: Metal uptake in plants and health risk assessments metal-contaminated smelter soils, Land Degrad. Dev., 785–792, doi:10.1002/ldr.2237, 2013

Sacristán, D., Peñarroya, B., and Recatalá, L: Increasing the knowledge on the management of cu-contaminated agricultural soils by cropping tomato (*Solanum Lycopersicum* L.), Land Degrad. Dev., 26, 587–595. doi:10.1002/ldr.2319, 2015.

Saffari, V. R. and Saffari, M.: Effect of treated municipal wastewater on bean growth, soil chemical properties, and chemical fractions of zinc and copper, Arab. J. Geosci., 6, 4475–4485, 2013.

Saleemi, M. A.: Environmental assessment and management of irrigation and drainage scheme for sustainable agriculture growth, Environ. Protection Agency Bull. (Lahore), 64 pp., 1993.

Salomons, W. and Forstner, V.: Trace metal analysis on pollution sediments 11. Evaluation of environmental impact, Environ. Technol. Lett., 1, 506–517, 1980.

Salwa, F. E., Shalaby, A., and Bahy El Deen, A.: Water management problems associated with urban sprawl in Gharbia Governorate, Egypt using remote sensing and GIS, Inter. J. of Adva. Rem. Sens. & GIS, 2, 243 –259, 2013.

Sanità di Toppi, L. and Gabbrielli, R.: Response to cadmium in higher plants, Environ. Exp. Bot., 41, 105–130, 1999.

Singh, R. P. and Agrawal, M.: Effects of sewage sludge amendment on heavy metal accumulation and consequent responses of *Beta vulgaris* plants, Chemosphere, 67, 2229–2240, 2007.

Stephenson, M., Motycka, M., and La Verock, M.: Recycling of Cd from sediment to water in an experimentally contaminated lake, in: International Conference Metals in the Environment, Hamburg, vol. 1, 1995.

Stephenson, R. J. and Sheldon, J.: Coagulation and precipitation of mechanical pulping effluent. Removal of Carbon, colour and turbidity, Water Res., 30, 781–792, 1996.

Thuy, L. T., Nguyen, N. V., and Tu, T. L.: Anthropogenic input of selected heavy metals (Cu, Cr, Pb, Zn and Cd) in aquatic sediments of Hochiminh City, Vietnam, 2007.

Tu, C., Ma, L. Q., and Bondada, B.: Arsenic accumulation in the hyperaccumulator Chinese brake and its 957 utilization potential for phytoremediation, J. Environ. Qual., 31, 1671–1675, 2002.

US Environmental Protection Ageency: Screening level ecological risk assessment protocol for hazardous waste combustion facilities, vol. 3, Appendix E: Toxicity referencevalues, EAP530-D99-001C, 1999.

Wang, M., Song, H., Chen, W., Lu, C., Hu, Q., and Ren Z.: Cancer mortality in a Chinese population surrounding a multi-metal sulphide mine in Guangdong province: an ecologic study, BMC Public Health, 11, 319, doi:10.1186/1471-2458-11-319, 2011.

Ye, M., Sun, M., Liu, Z., Ni, N., Chen, Y., Gu, C., Kengara, F. O., Li, H., and Jiang, X.: Evaluation of enhanced soil washing process and phytoremediation with maize oil, carboxymethylâ-cyclodextrin, and vetiver grass for the recovery of organochlorine pesticides and heavy metals from a pesticide factory site, J. Environ. Manage., 141, 161–168, 2014.

Zhang, H., Lin, Y. H., Zhang, Z., Zhang, X., Shaw, S. L., Knipping, E. M., Weber, R. J., Gold, A., Kamens, R. M., and Surratt, J. D.: Secondary organic aerosol formation from methacrolein photooxidation: roles of NO_x level, relative humidity, and aerosol acidity, Environ. Chem., 9, 247–262, 2012.

Zhao, K., Liu, X., Xu, J., and Selim, H.: Heavy metal contaminations in a soil–rice system: identification of spatial dependence in relation to soil properties of paddy fields, J. Hazard. Mater., 181, 778–87, 2010.

Zhuang, P., McBride, M. B., Xia, H., Li, N., and Li, Z.: Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China, Sci. Total Environ., 407, 1551–1561, 2009.

Żukowska, J. and Biziuk, M.: Methodological evaluation of method for dietary heavy metal intake, J. Food Sci., 73, 21–9, 2008.

SED
doi:10.5194/se-2015-34

Table 1. Total concentrations of heavy metals in soils irrigated by water from Zefta drain, drain No. 5 and Baher El Mlah.

Parameters	Units	Soils around of No. 5 drain	Soils around of Zefta drain	Soils around of Baher El Mlah	Upper limit of background total heavy metals (Chen et al., 1992)
pH		7.8–8.3	7.8–8.5	7.3	–
$CaCO_3$	%	4.1–8.2	3.28–5.74	4.1	–
Fe	$mg\,kg^{-1}$	1226–4989	1790–4757	933	–
Zn	$mg\,kg^{-1}$	102–187	184–449	54	120
Mn	$mg\,kg^{-1}$	341–800	172–853	264	–
Cu	$mg\,kg^{-1}$	82–167	123–386	60	35
Cd	$mg\,kg^{-1}$	13–28	21–33	11	3
Pb	$mg\,kg^{-1}$	48–92	55–80	53	120
Ni	$mg\,kg^{-1}$	55–133	104–164	31	60

SED
doi:10.5194/se-2015-34

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

Table 2. Bioconcentration factors of heavy metals in maize and rice grown in soils irrigated of drains (Zefta and No. 5) and limits of heavy metals.

Elements	No. 5 drain		Zefta drain		Limits of heavy metals*
	Rice	Maize	Rice	Maize	$mg\,kg^{-1}$
Fe	0.29	0.35	0.54	0.34	–
Mn	3.40	2.97	1.71	1.51	300–500
Cu	0.59	1.54	1.75	1.83	20–100
Zn	2.82	1.71	1.44	1.32	100–400
Pb	6.73	6.83	5.26	5.66	30–300
Cd	6.14	6.45	6.55	2.26	5–30

* Kabata-Pendias and Pendias (1992).

SED

doi:10.5194/se-2015-34

Table 3. The chemical analysis waters of drains Zefta and No. 5. and Baher El Mlah.

Parameters	Units	No. 5 drain	Zefta drain	Baher El Mlah	Water criteria for irrigation water (a)
pH		9.8	12.2	7.2	6.5–8.4
TDS	$mg L^{-1}$	1016	1130	334	2000
SAR		17.3	18.2	6	6–12
BOD_5	$mg L^{-1}$	540–723	442–632	–	40 *
COD	$mg L^{-1}$	882–2301	978–2445	–	60 *
Fe	$mg L^{-1}$	0.09	0.56	0.01	5.0
Zn	$mg L^{-1}$	0.02	0.037	–	2.0
Mn	$mg L^{-1}$	0.68	2.91	0.03	0.2
Cu	$mg L^{-1}$	0.15	0.28	0.12	0.2
Cd	$mg L^{-1}$	0.03	0.07	0.001	0.01
Pb	$mg L^{-1}$	1.05	0.18	0.05	5.0
Ni	$mg L^{-1}$	0.12	0.31	0.02	0.2

* E.C.S (48/1992).

SED
doi:10.5194/se-2015-34

Table 4. Average of heavy metal concentrations, contaminant factor and distribution coefficients (Kd) in sediments of drain No. 5 compared with toxicological reference Value (US EPA, 1999).

Elements	Conc. ($mg\,kg^{-1}$) Mean ± SD	Et	Cf	Kd ($L\,kg^{-1}$)
Zn	647.5 ± 36.7	110	6.25	32375.0
Mn	2125.0 ± 74.3		12.67	3125.0
Cu	425.0 ± 12.4	16	4.25	2833.3
Cd	97.5 ± 4.6	0.6	9.55	3250.0
Pb	145.0 ± 4.5	31	4.8	138.1
Ni	195.0 ± 9.8		7.33	1625.0

Et: US EPA Toxicity reference value.
Cf: Contaminant factor.
Kd ($L\,kg^{-1}$) Distribution coefficients.

SED
doi:10.5194/se-2015-34

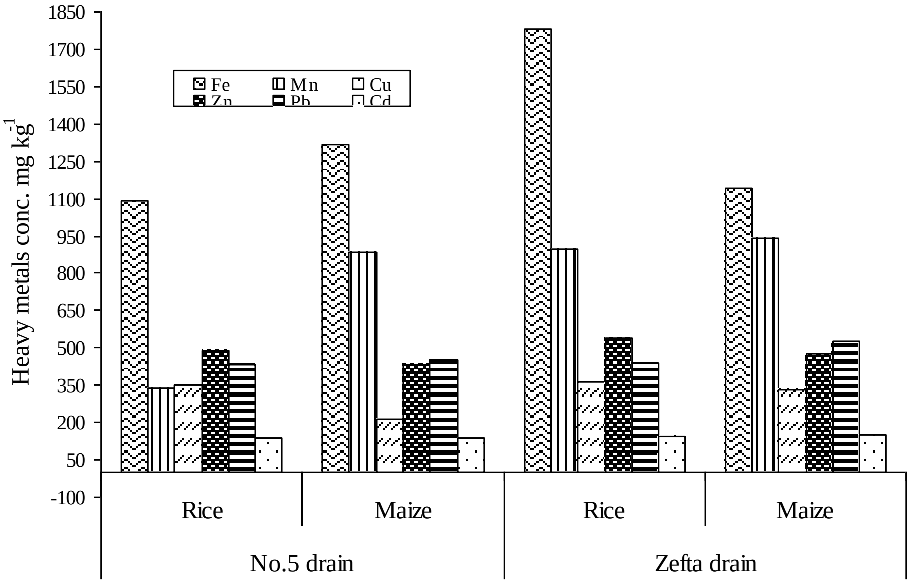

Figure 1. Concentration of heavy metals in maize and rice grown in soils irrigated of drains (Zefta and No. 5).

SED
doi:10.5194/se-2015-34

Effect of polluted water on soil, sediments and plant contamination

E. Mahmoud and A. M. Ghoneim

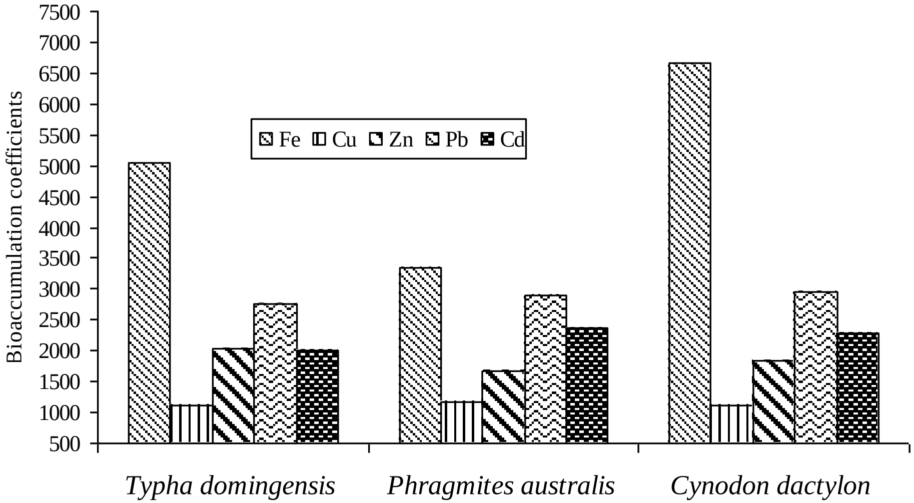

Figure 2. Bioaccumulation coefficients of heavy metals in *Typha domingensis*, *Phragmites australis* and *Cynodon dactylon* grown in Zefta drain.

SED
doi:10.5194/se-2015-34

E. Mahmoud and A. M. Ghoneim