Effect of irrigation with mixed drainage water of EL-Mehalla EL-Kobra area, Gharbia governorate on metal contents in soils and plants

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ABSTRACT

The discharge of industrial and municipal wastewater without treatment in drains Zefta and No.5 is becoming a problem for many farmers in EL- Mehalla EL Kobra area there waters that contains high levels of contaminants at levels considered hazardous to the ecosystem. Water, soil, plant and sediment samples were collected from EL- Mehalla EL Kobra area to evaluate the impact of industrial and municipal wastewater on the ecosystem. The results showed that heavy metals, pH, sodium adsorption ratio (SAR), BOD and COD in the water of drains Zefta and No.5 were exceeded limits for irrigation. The study demonstrated that the bioaccumulation coefficients of *Cynodon dactylon* growing in Zefta drain were higher than *Phragmites australis* and *Typha domingensis*. Therefore, these species can be considered as hyperaccumulators, for decontamination of polluted water. This study also demonstrated that heavy metals of irrigated soils from drains Zefta and No.5 exceeded the upper limit of background heavy metals. The results showed that the shoot of maize contains more Fe, Cd, Mn and Pb concentrations than the rice shoot in the irrigated area with drainage water from drains No.5 and Zefta. Thus, the industrial and municipal wastewater in EL- Mehalla EL Kobra area must be treated before discharge in drains (Zefta and No.5) and remediation of polluted soils from heavy metals.

Keywords: wastewater, Bioaccumulation, ecosystem, impact, hazardous, heavy metals, decontamination, hyperaccumulators, irrigation

INTRODUCTION

EL- Mehalla EL Kobra area is density populated and contains 83 industrial factories such as textile, food, oil, and other industries. The quantity of industrial and municipal wastewater is around 243500 m^3 day^{-1} (107500 m^3 day^{-1} of municipal sewage and 136000 m^3 day^{-1} of industrial wastewater), which discharge into Zefta Drain (flow, 354240 m^3 day^{-1}) and No.5 Drain (flow, 265248 m^3 day^{-1}) without treatment except 63627 m^3 day^{-1} of municipal wastewater can be treated in Dawakhlia plant. Wastewaters from municipal and industrial factories are becoming a problem for many farmers. It often 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.

Pollution resulting from industrial growth has often been overlooked in the past, due to a lack of awareness of the extended of the problems, environmental hazards and economic reasons. Moreover, the lack of specific environmental protection laws meant that any necessary remedial action was left to the discretion of the single operators, with the result that once activity had ceased the sites, generally severely degraded, were often simply abandoned. However, more recently, a heightened awareness of the harmful effects of soil, air and water pollution and enhanced public perception have changed attitudes towards environment issues. Nowadays remedial measures for eliminating or confining sources of pollution or for the remediation and reclamation of contaminated soils or more frequently being adopted, also with the economic objective converting the degraded land to other uses (Ciccu et al., 2001).

Industrial wastewater generally contains contaminants such as suspended solids, dissolved organic matters, heavy metals, and other contaminants at levels considered hazardous to the environment and could pose a risk to public health. 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 are considered to be toxic occurred high concentrations (Angelova et al. 2004). The objectives of this study were to evaluate the Effect of irrigation with mixed drainage water of EL-Mehalla EL-Kobra area, Gharbia governorale on metal contents in soils, plants and sediments

MATERIALS AND METHODS

Forty surface (0 – 30 cm) and subsurface (30 – 60 cm) soil samples were collected from cultivated lands EL –Mehalla El-Kobra, Gharbia Governorate which are irrigated with drainage water from drains No.5 and Zefta, and Fifteen samples which are irrigated from Baher El Mlah water. 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 and sediment samples with concentrated HNO_3 and $HClO_4$ acids (Page, 1982). Samples of rice and maize plants (age 65 days) 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 to determine heavy metals. The plant samples were dried in oven at 75° C for 72 hours after washed with digested with concentrated H_2SO_4 and H_2O_2 to determine heavy metals by atomic absorption spectrophotometer (Chapman and Pratt, 1961)

Seventeen water samples were collected from drains No.5 and Zefta at different times (March 2006 to March 2007) at about 20 cm below water surface and chemically analyzed for pH, EC, SAR, BOD_5, COD and heavy metals (APHA, 1995).

RESULTS AND DISCUSSION

Quality of Drainage Water;

Concentrations of BOD and COD ranged from 442 and 978 mg l^{-1} to 978 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 No.5 Drain, respectively (Table 1). This water would be classified as high strength (Metcalf and Eddy, 2003). The BOD/COD ratio in the drains of Zefta and 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 in the drains of Zefta and No.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 ware higher than in water of Baher El Mlah which could be attributed to discharge of industrial wastewater into the two drains without treatment. Heavy metals of the drains of Zefta and No.5 exceeded the criteria limits for irrigation water (FAO, 1985 and E.C.S, 48/1982).

Heavy Metals of Sediments:

The high heavy metal concentrations in sediments of drain No.5 (Table 2) 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 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.

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 Table 3. 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 that contain >100 mg/kg of Cd, >1000 mg/kg of Ni and Cu, or >10,000 mg/kg of Zn and Mn (dry weight) when grown in metal-rich medium (Zavoda et al., 2001). The use of plants for decontamination 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.

Soil Contamination:

The range of heavy metals in surface and subsurface 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

(4). In general, the concentrations of heavy metals in soils irrigated from drains of Zefta and 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 1). The level of heavy metals of soils irrigated from Baher EL Mlah were lower than there of the around soils of Zefta drain and drain No.5. This can be attributed to the low concentration of heavy metals in the water of observed Baher El Mlah. 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.

Plant 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 drain No.5 (Table 5). This was due to the high total heavy metal contents in that soils (Table 4).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 for Cd, Pb, Zn and Cu, respectively. It is clear from (Table 5) the higher concentrations of Cd in rice and maize plants than 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.

Conclusion

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 those drains receiving high loads of pollutant such as Zefta and No.5 drains. This was confirmed by the low water quality and polluted soils especially by heavy metals in the EL- Mehalla EL kobra area. So, the industrial and municipal wastewater in EL- Mehalla EL kobra area must be treated before discharge in drains (Zefta and No.5) and remediation of polluted soils from heavy metals

Table 1 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
SUM		2.14	4.347	0.231	
Heavy metal Loads ton day^{-1}		2.14*265248** = 0.57	4.347*354240** = 1.46		

* E.C.S (48/1982)
** Discharge

Table 2 Average of heavy metal concentrations and distribution coefficients (Kd) in sediments of Drain No.5 compared with toxicological reference value (US EPA, 1999)

Elements	Concentrations mg kg^{-1} Measured	US EPA Toxicity reference value	Kd L kg^{-1}
Zn	647.5	110	32375.0
Mn	2125.0		3125.0
Cu	425.0	16	2833.3
Cd	97.5	0.6	3250.0
Pb	145.0	31	138.1
Ni	195.0		1625.0

Table 3 Bioaccumulation coefficients of heavy metals in *Typha domingensis*, *Phragmites australis* and *Cynodon dactylon* grown in Zefta drain

Elements	*Typha domingensis*	*Phragmites australis*	*Cynodon dactylon*
Fe	19053	11348	27651
Mn	158	65	268
Cu	1125	1160	1107
Zn	2040	1675	1851
Pb	2750	2888	2944
Cd	2000	2357	2285

Table 4 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

Table 5 Concentration of heavy metals in maize and rice grown in soils irrigated of drains (Zefta and No.5) compared to limits of heavy metals

Elements	Units	No. 5 drain		Zefta drain		Limits of heavy metals *
		Rice	Maize	Maize	Rice	
Fe	mg kg^{-1}	1092	1315	1780	1144	-
Mn	mg kg^{-1}	340	882	898	940	300 - 500
Cu	mg kg^{-1}	352	213	366	332	20 - 100
Zn	mg kg^{-1}	492	430	540	478	100 - 400
Pb	mg kg^{-1}	430	452	442	530	30 - 300
Cd	mg kg^{-1}	138	140	142	153	5 - 30

* Kabata - Pendias and Pendias (1992)

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REFERENCES

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

Angelova, V., Ivanova, R.; Delibaltova, V. and Ivanov, K. 2004. Bio-accumulation and distribution of heavy metals in fiber crops (fax, cotton and hemp). Industrial Crops and Products, 19, 197-205.1.

APHA 1995. Standard Methods for Examination of Water and Wastewater. AWWA, and WEF, Washington , D.C.(19th . ed.)

Brooks, R, R. 1998. Plants that hyperaccumulated heavy metals CAB international. London, UK. ISBN.

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

Chen, Z. S., Lee,D.Y.; Wong, D. and Wang, Y. P. 1992. Effect of various treatment 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, pp 277- 292

Ciccu,R.; Ghiani,M.; Peretti,R.; Serci,A. and Zucca, A. 2001. Heavy metals immobilization using fly ash in soils contaminated by mine activity. http:// www.flyash.inlo E.C.S (Egyptian chemical standards), low No. 48/1982. Protection of the Nile River and water stream from pollution; Ministry of irrigation, Cairo, Egypt.

F.A.O.1985. Water quality for agriculture. Ayers, R.S. and westcot D.W. FAO. Irrigation and Drainage, Paper No. 29.Rev.I Rome , Fao. 174 P.

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

Kabata - Pendias and Pendias. 1992. Trace Elements in Soils and Plants CRC.Press Boca Raton , FL

Lasheen, M. R.; Abd EL-Shafy. H.H. and Ashmawy, A.M .1981.

Selected metals in River water Bull Nat. Res. Cent., Egypt, 6, 578.

Li, Gwo - Chen, Haw-Tarn Lin, and Chi – Sen Lai .1994. Uptake of heavy metals by plants in Taiwan. Paper from conference title: Biogeochemistry of trace elements. Environ Geochemist.Health .p.153-160.

Linsley, R. K.; Joseph, B.; Franzini, D. L. And Freyberg, G. T. 1992. Water Resources Engineering. Fourth Edition. McGraw-Hill, Inc., New York.

Loeppert, R. H. and Suarez D. L. 1996. Carbonate and gypsum p.437-474. In D. L. Sparks et al. (ed) Methods of Soil Analysis. Part3. SSSA Book Ser.5. SSSA, Madison, WI.

Mace, J, E. and Amrhein, C. 2001. Leaching and reclamation of a soil irrigated with moderate SAR waters. Soil Sci. Soc. Am. J. 65: 199 - 204.

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

Page, M.A.(ed.). 1982. Methods of soil analysis. Part 2 .Academic press, New York.

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

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

Stephenson, M.; Motycka, M. F. and la Verock, M. 1995. Recycling of Cd from sediment to water in an experimentally contaminated lake. International conference metals in the environment. Hamburg vol. 1

Stephenson, R. J. and Sheldon, J. B. 1996. Coagulation and precipitation of mechanical pulping effluent. Removal of Carbon, colour and turbidity. Wat. Res. Vol. 30, No.4, pp. 781-792

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

US Environmental Protection Ageency 1999. Screening level ecological risk assessment protocol for hazardous waste combustion facilities. vol.3. Appendix E: Toxicity referencevalues.EAP530-D99-001C, from http:// www.epa.gov /epaoswer/hazwaste/combust/eco--risk/volumr3/appx-e.pdf.

Zavoda, J.; T. Cutright; J. Szpak and E. Fallon (2001). Uptake, selectivity, and inhibition of hydroponics treatment of contaminants. J Environ Eng ;127(6): 502– 8.

الملخص العربي

تأثير الرى بمياه الصرف المخلوطة على محتوى التربة والنبات من المعادن بمنطقة المحلة الكبرى بمحافظة الغربية

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اصبح التخلص من مياه الصرف الصناعى والصحى بدون معالجة مشكلة لمعظم فلاحين منطقة المحلة الكبرى حيث تحتوى هذه المياه على العديد من الملوثات وصلت الى مستوى يضر بالنظام البيئي المحيط . ولبحث هذه المشكله أخذت عينات من المياه ، الارض ، والنبات والرواسب من منطقة المحلة الكبرى وذلك لتقييم اثر هذه المياه على النظام البيئى المحيط . ولوضحت النتائج ارتفاع تركيز المعادن الثقيلة، رقم الحموضة (pH)، نسبة الصوديوم المدمصه (SAR)، الاكسجين الكيماوى المطلوب (COD) والاكسجين الحيوي المطلوب (BOD) فى مياه مصرفى زفتى ونمره (٥). وقد تجاوزت تركيزات المعادن الثقيلة , COD , BOD الحدود المسموح بها فى الرى .اوضحت النتائج ايضا ارتفاع قيمة Kd (معامل توزيع المعادن الثقيلة بين الراسب والمياه) فى نبات النجيل عن نبات الطايفة والحجنة النامية فى مصرف زفتى. وقد تجاوز تركيز المعادن الثقيلة فى الاراضى المروية من مصرفى زفتى ونمره (٥) الحدود المسموح بها للمعادن الثقيلة. وكان المجموع الخضرى لنباتات الذره يحتوى على تركيز عالى من الحديد ، الكادميوم ، المنجنيز ، والرصاص عن نباتات الأرز والتى تروى من نفس مياة هذة المصارف ويرجع ذلك الى ان الأرز ينمو تحت الظروف الغدقة ويحدث فى مثل هذه الظروف ترسيب لهذه العناصر فى صورة معقدات مع الكبريت. لذلك يجب معالجة مياه الصرف الصناعى والصحى لمنطقة المحلة الكبرى قبل صرفها فى مصرفى زفتى ونمره (٥) وكذلك معالجة الاراضى الملوثه بالعناصر الثقيلة.