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IMPLICATIONS OF USING BELBAIS DRAIN WATER FOR IRRIGATION OF WHEAT IN THE NORTH EAST REGION OF EGYPT

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ABSTRACT

Wastewater may be used for complimentary irrigation of crops in the North East region of Egypt. Implications of using such wastewater on accumulation of heavy metals in soil and plant must be assessed. Water, soil and wheat samples were collected from 10 sites (with 5 km distance between sites) along the drain of Belbais and analyzed for their contents of Pb and Co. Contents of Pb in water were within the permissible levels recommended by FAO; however, there was a significant progressive increase from site 1 to 5 along the drain (North-East direction) beyond which gradual decrease occurred. The Co content in wastewater exceeded the acceptable limits and progressively increased from site 1 to 10. Contents of Pb and Co in soil were higher than the corresponding maximum acceptable levels. Wheat plants were sampled and lead contents in straw and grain were within the permissible level. Cobalt content in wheat straw was higher than the permissible level and exceeded the permissible levels in grains. A positive significant correlation existed between Co content in plant and in water. Using such water for complimentary irrigations may be of potential health hazards.

Keywords: soil pollution; water pollution; Belbais drain; wheat

INTRODUCTION

The term "heavy metal" is widely used to refer to the group of metals and metalloids of relatively high atomic mass (>5 Mg m^{-3}) (Alloway, 2013). Heavy metals enter the ecosystem as a result of expanding urbanization (Meng et al., 2008) through vehicle exhaust (Li *et al.*, 2001), mining and smelting activities (Nagajyoti *et al.*, 2010), sludge, livestock manures (Nicholson *et al.*, 2003), industrial discharges into soils and water (Li *et al.*, 2001), beside of the inorganic fertilizers (Abdelhafez *et al.*, 2012).These heavy metals persist in the environment and do not undergo degradation (Greger, 2005). Some heavy metals e.g. Fe^{2+} and Co^{2+} are beneficial for plants when found at low concentrations in soils; however, they become toxic under elevated concentrations (Williams *et al.*, 2000). Others, for example Cd^{2+} and Pb^{2+}, are toxic even at low concentrations (Clemens, 2001).

Plants grown in contaminated sites absorb heavy metals mostly through the younger parts of roots as casparian strips are not well developed (Greger, 2005). The absorbed heavy metals result in toxicity symptoms (Hall, 2002). However, some plants are tolerant (Keller *et al.*, 2003) and can accumulate amounts of heavy metals far exceeding their content in soil without showing toxicity symptoms (Raskin *et al.*, 1994). One third of the developing world faces water scarcity problems (Keller *et al.*, 2000; Khurana and Singh, 2012). One of the challenges facing the Egyptian government is the limited water resources (El-Sadek, 2010). Using treated wastewater is one of the main aspects to be considered under conditions of water scarcity (Pereira *et al.*, 2002). It is already in use by the Egyptian farmers in some areas of Egypt to overcome the shortage of water for irrigation (Loutfy, 2011).

Irrigation with sewage water could increase the level of heavy metals in soil (Sharma *et al.*, 2007). Consuming plants irrigated with contaminated water is of a potential health risk (Järup, 2003; Chen *et al.*, 2005; Kachenko and Singh, 2006; Parashar and Prasad, 2013; Abdelhafez *et al.*, 2014; Abdelhafez *et al.*, 2015). Lead is a well known neurotoxins (Peralta-Videa *et al.*, 2009) and Co induce apoptosis and necrosis with inflammatory responses (Simonsen *et al.*, 2012).

Environmental monitoring of heavy metals in areas irrigated with waste water is required to ensure safe production of food on one hand and to control environmental. The current study aimed at investigating the implications of using the waste water of Belbais drain for complementary irrigation of the soils adjacent to this drain with regard to lead and cobalt accumulation in soils and wheat plants grown thereon.

MATERIALS AND METHODS

Location description

Belbais drain is a main drain receiving wastewaters from Cairo and discharge its wastes into Bahr El-Baqar drain (Taylor *et al.*, 1993; Lovelady *et al.*, 2009). The water of the drain contains a mixture of sewage and industrial wastewaters (treated and untreated). It is 60 km long (Stahl et al., 2009), serving 39 228 ha (Lovelady *et al.*, 2009). Farmers sometimes were forced to use water of this drain for the complimentary irrigation of their crops (Hamed *et al.*, 2011); unaware of the negative implications of using such water.

Water, soils and plant sampling

Water samples were collected from 10 sites along the drain of Belbais with approximately 5-km distance apart between successive sites as shown by Figure 1.

Fig 1. Location description and site sampling

Chemical properties of the water obtained from the investigated sites are presented in Table 1.

Soils irrigated with Belbais drain waters at the aforementioned sites were sampled to a depth of 30 cm. The soil samples were air dried, crushed and sieved to pass through a 2 mm sieve. Physical and chemical analyses were determined according to the standard methods outlined by Klute (1986) and Page *et al.* (1982) and the results are shown in Table 2.Wheat plants grown on locations of the sites were sampled, washed with deionized water, separated into straw and grains, oven dried at 70 C for 48 h and grounded to pass through a 5mm sieve.

Table 1. Chemical properties of Belbais drain water

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
pH	7.3	7.3	7.1	7.3	7.2	7.3	7.3	7.3	7.3	7.2
EC, dS m-1	1.5	1.6	1.6	1.6	1.6	1.7	1.6	1.5	1.6	1.6
SAR	4.0	3.9	4.2	3.8	4.2	4.7	5.0	3.8	4.2	4.1

SAR: sodium Adsorption Ratio

Table 2. Chemical and physical properties of the investigated sites

Sites	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
EC*, dS m^{-1}	1.3	1.9	8.4	1.9	1.7	1.8	1.7	1.4	2.2	2.5
pH**	7.4	7.3	7.4	7.3	7.3	7.2	7.4	7.3	7.1	7.3
$CaCO_3$, g kg^{-1}	31.6	29.7	38.8	32.1	27.0	31.4	25.2	31.2	29.0	28.6
OM, g kg^{-1}	13.2	19.8	11.9	17.5	14.1	12.3	12.2	19.2	14.5	15.5
					Particle size distribution					
Sand, %	39.6	35.1	32.5	29. 5	29.6	28.7	28.7	27.3	28.6	26.5
Silt, %	42.1	45.6	48.7	49.1	50.1	52.2	51.1	53.2	54.1	52.4
Clay, %	18.3	19.3	18.8	21.4	20.3	19.1	20.2	19.5	17.3	21.2
Textural Class	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam

***EC was determined in soil paste extract**
****pH was determined in 1:2.5 (soil:water) suspension**

Soil, water and plant analyses

Soil samples were acid digested in a block digestor using concentrated mixture of HNO_3 and H_2O_2 according to Lu *et al.* (2010). Plant material samples were acid digested according to Peterburgski (1968). The sampled water at each of the previously indicated sites was analyzed for its chemical characteristics according to Page *et al.* (1982). Pb and Co contents were determined in the digests of soil and plant straw and grains as well as the wastewater samples using Atomic Absorption Spectrophotometer (PERKIN-ELMER 2380). According to Tüzen (2003), determination of heavy metals in soils and plant could be done with good accuracy by this apparatus.

Data analysis

The collected data were statistically analyzed using Minitab 15 statistical software according to the analysis of variance and correlation studies ($P<0.05$). The graphs were plotted using Sigma Plot 10 program.

RESULTS AND DISCUSSION

Pb and Co in wastewater samples of Belbais drain

Fig 2 shows that Pb content in the wastewaters increased significantly from site 1 along the pathway of Belbais drain until it reached site 5 where it recorded its highest value. Beyond site 5, Pb tended to decrease gradually but significantly until the end site 10. This decrease in Pb concentrations is probably a result of the dilution of Pb with the water drained from the surrounding arable lands on one hand and sorption of Pb that must have accrued on the colloidal fractions (mineral and organic) of the sediments in bottom and sides of the drain. Lead is highly sorbed on soil sediments and probably fixed in the inner-sphere surface reactions (Appel and Ma, 2002) with relatively low desorption rate from soils (Strawn and Sparks, 2000). On the other hand, Co content increased in wastewater progressively through its pathway along

Belbais Drain. The increases that occurred in Pb content in the water stream from site 1 to site 5 beside of the continuous increase in Co content in wastewater refer to potential hazards for both soils and plants irrigated with such Pb and Co-contaminated waters. It is more likely that some factories discharged their wastewaters directly into the drain between sites 1 to 5. According to the maximum acceptable limits of Pb and Co recommended by the FAO (1994) which are 5 and 0.05 mg L^{-1}, respectively; the level of Pb in wastewater of Belbais drain is still below the permissible limits for irrigation water; whereas, that of Co exceeded the permissible limits.

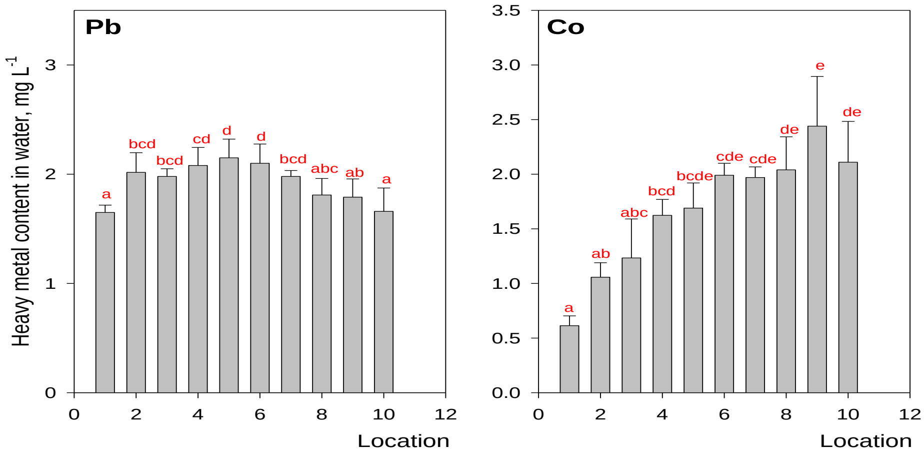

Fig 2. Pb and Co contents in the sewage water of Belbais drain

Pb and Co in soil

Contents of either Pb or Co in soil did not change significantly along Belbais drain. Results shown in Fig 3 reveal that total Pb in soil sites ranged between 340 and 537 mg kg^{-1}; whereas, the corresponding Co contents ranged between 113 and 151 mg kg^{-1}, respectively. According to Lacatusu (1998) and Co[a]Kun et al. (2006), the Dutch system of evaluating soil contamination with heavy metals suggested that the maximum acceptable levels of Pb and Co in soils are 150 and 50 mg kg^{-1}, respectively. Thus, Pb and Co concentrations in soils were higher than the corresponding maximum permissible ones in the arable lands throughout the different soil sites along Belbais drain. This pollution might lead to direct and indirect toxic effects on the grown plants (Chibuike and Obiora, 2014) and this might have potential hazardous effects on man and animals feeding on plant grown in these soils. Wheat is an important crop worldwide (Curtis, 2002) and in Egypt, it is a strategic crop (Kheralla *et al.*, 2000). Its grains are edible by humans (Kobayashi *et al.*, 2008) while the straw is fed by animals (Basu *et al.*, 2002; Villas-Bôas *et al.*, 2002). Accordingly, occurrence of heavy metals in the plants grown in these soils might give more precise indicator on the level of the contaminants that might accumulate in the edible plant parts. However, there is no pattern of soil pollution shown from the levels of Pb and Co through the different sites. Such pollution trends probably indicate that most Pb and Co pollution found in soil came from sources other than the water of Belbais drain. Airborne Pb might have taken place in this concern (Bellis, 2001).

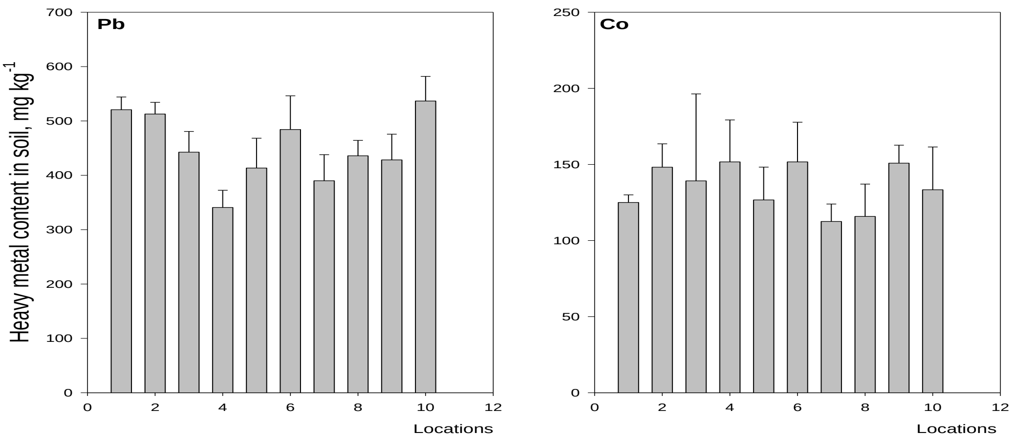

Fig 3. Pb and Co contents in the arable lands irrigated with Belbis drain wastewater

Pb and Co in wheat straw

Fig 4 reveals that Pb contents in wheat straw ranged between 8.17 to 15.00 mg kg-1 i.e within the normal level (1–13 mg kg^{-1}) reported by Misra and Mani (1991). Although, the results obtained herein indicate that soils are heavily polluted with Pb;

however, the usual agricultural practicies e.g. applying P fertilizers can effectively reduce Pb availability in soil (Xie *et al.*, 2006). Moreover, lead uptake takes place mainly through Ca ion channels (Pourrut *et al.*, 2011). Ca salts in the investigated soils can antagonize Pb uptake (Brunet, 2008). Also, translocation of Pb from root to straw is limited (Pourrut *et al.*, 2011). Thus, low concentrations of Co were detected in wheat straw.

Cobalt contents in wheat straw ranged from 12.50 to 27.50 mg kg^{-1} i.e. exceeded the normal levels in plants which ranges between 0.05 and 0.5 mg kg^{-1} according to Misra and Mani (1991). Although, cobalt is an essential component of several enzymes and co-enzymes (Palit *et al.*, 1994) and can increase wheat yield when found at low concentrations (Wen-hua *et al.*, 2004); however, excess cobalt in plant tissue has a significantly inverse relationship with the wheat yield (Aery and Jagetiya, 2000). In general, wheat is an excluder for Co (Collins *et al.*, 2010). Thus, the plants grown on soils of the investigated area didn't show toxic symptoms and probably Co, on the other hand, stimulated the plant growth.

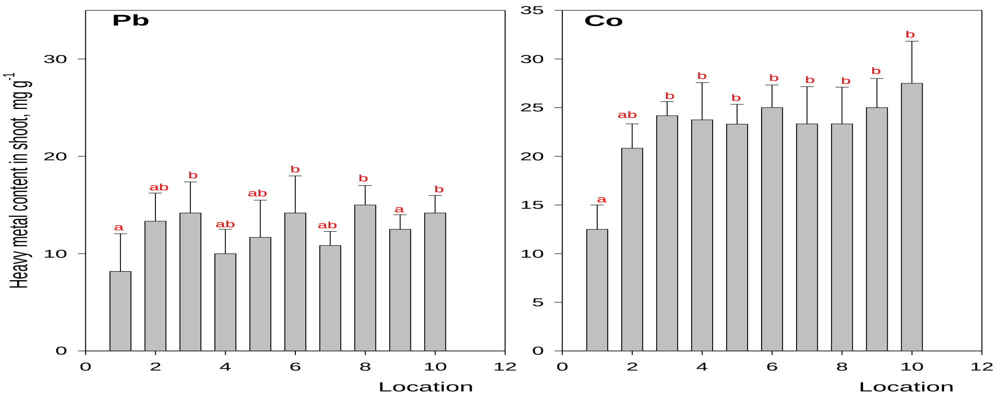

Fig 4. Pb and Co contents in wheat straw of plants irrigated with Belbais drain wastewater

Pb and Co in wheat grain

Fig 5 indicates that the contents of Pb and Co in wheat grains ranged between 77 to 160 µg Pb kg^{-1} and between 36 to 85 µg Co kg^{-1}, both being lowest in site 1 and increased progressively to achieve the highest values in site 10. The permissible level of Pb in wheat grains is 0.4 mg kg^{-1} (Stefanoviæ *et al.*, 2008). This means that Pb content in grains of wheat grown on the investigated soils is still within the permissible levels and, hence, no potential Pb hazard is expected due to using the dietary intake of these grains.

Cobalt can be translocated to grains in high concentrations (Zeller and Feller, 1999). Based on the daily consumption ration of wheat which is equal to 100 g, the daily intake of Co per person would be of about 3.6 to 8.5 mg person^{-1} day^{-1} while the reference daily allowance of Co intake according to Beladel *et al.* (2012) should not exceed 0.12 mg Co person^{-1} day^{-1}. Thus, potential Co hazard is expected upon dietary intake of wheat grains.

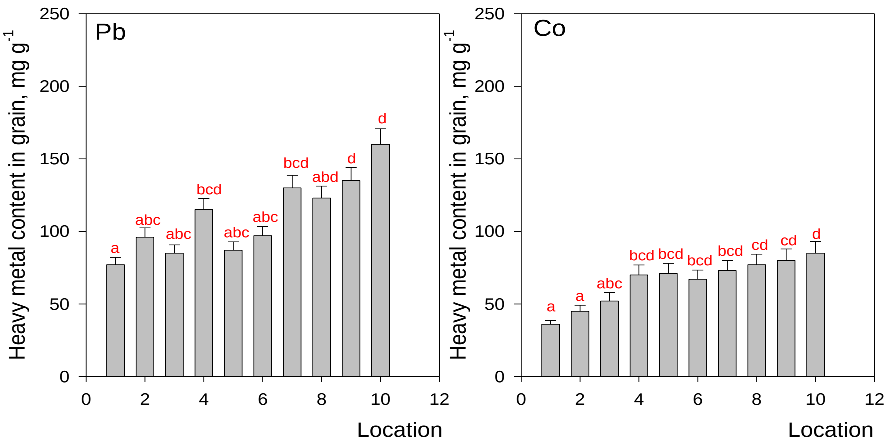

Fig 5. Pb and Co contents in grains of plants irrigated with Belbais drain wastewater

Soil-water-plant relations of Pb and Co

Table 2 shows that concentrations of Pb in wheat straw and grains were not significantly correlated with the corresponding contents in soils or waste waters. Probably, factors other than the considered ones had more influences on Pb content in plant. Areal uptake of Pb might take place (Pallavi and Shanker, 2005; Uzu et al., 2010) from different sources such as leaded gasoline and pesticides (McBride *et al.*, 2012). Within plants, it was reported that Pb is relatively immobile (Pourrut *et al.*, 2011). Thus, there is no wonder to find out that Pb contents in grains was not significantly correlated with those in straw. On the other hand, Co concentrations in wheat straw were significantly correlated with those in the drain wastewater. There was also a significant relation between Co contents in wheat straw and those in grains. Probably, because of the intermediate mobility of Co within the wheat plants (Riesen and Feller, 2005). The obtained results indicate that using such water for complimentary irrigation might be of significant implications on the uptake of Co by wheat and its translocation to the grains. It is worthy to indicate that using such wastewaters for complementary irrigation of crops recorded insignificant effects on the accumulation of Co or Pb in soils. Factories wastes and discharges along the drain might bring appreciable concentrations of heavy metals to soils exceeding those introduced through the waste waters.

Table 3. Soil-water-plant correlation of Pb and Co

	Pb			Co		
	Soil	**Water**	**Straw**	**Soil**	**Water**	**Straw**
Water	-0.538			0.035		
Straw	0.245	0.070		0.249	0.807*	
Grain	-0.051	-0.398	0.300	-0.078	0.949*	0.812*

***Significant at P<0.05**

CONCLUSION

Lead content increased significantly in the wastewater along Belbais Drain from site 1 to 5. Beyond site 5, Pb content decreased gradually but significantly. Cobalt content increased in the wastewater progressively through its pathway along Belbais Drain from site 1 to 10. It is more likely that some factories that discharge their untreated industrial wastewaters directly into the stream of the drain account for such increases. Regular monitoring (24 h/day) of the wastewater discharge from factories to the drain is required to attain better environmental quality. Cobalt in the wastewater was below the acceptable limits recommended by FAO while Pb exceeded the acceptable limits. On the other hand, levels of Pb and Co in soils exceeded the maximum acceptable levels. The pattern of soil pollution in soils from site 1 to 10 probably indicates that most Pb and Co pollution in soil came from sources other than using the waste water of Belbais drain in irrigation. It seems that wheat is a Pb-excluder and/or can effectively minimize Pb translocation to wheat straw and grains. Thus, Pb content in both wheat straw and grains was within the normal levels. On the other hand, the level of Co in straw and grains exceeded the normal levels. Co contents in grain and straw were significantly correlated with their contents in the waste water and not with their contents in soil.

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تداعيات استخدام مياه الصرف في انتاج المحاصيل في منطقة شمال شرق جمهورية مصر العربية

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يضطر المزارعون أحيانا إلى استخدام مياه الصرف الصحي للري التكميلي للمحاصيل في منطقة شمال شرق مصر. التحقيق في الآثار المترتبة على استخدام مياه الصرف الصحي على تراكم المعادن الثقيلة في التربة والنبات هو مطلوب لضمان الانتاج الآمن من المواد الغذائية من جهة والسيطرة على التلوث البيئي من جهة أخرى. وقد تم جمع عينات من المياه، التربة والقمح من 10 مواقع على طول مصرف بلبيس وتحليل محتوياتها من الرصاص والكوبلت. تركيزات الرصاص في مياه الصرف الصحي كانت في حدود المستويات المسموح بها التي أوصت بها منظمة الغذاء و الزراعه (الفاو)؛ ومع ذلك، ارتفعت هذه التركيزات تدريجيا وبشكل ملحوظ من موقع 1-5 بعدها حدث انخفاض تدريجي. على الآخر، محتوى الكوبلت في مياه الصرف الصحي تجاوز الحدود المقبولة والتركيز زاد تدريجيا من موقع 1 إلى 10. في التربة، كانت تركيزات الرصاص والكوبلت أعلى من المستويات المقبولة القصوى المقابلة. في نباتات القمح المزروعة محتوى الرصاص في القش والحبوب كان ضمن المستوى العادي المسموح به ؛ في حين، كان محتوى الكوبلت في قش القمح أعلى من المستوى الطبيعي، وتجاوز الحدود المسموح بها في الحبوب بشكل مخيب للآمال. وثمة وجود ارتباط كبير بين محتوى الكوبلت في كل من القش أو الحبوب مع واحد المقابلة في مياه الصرف. وفي الختام، استخدام هذه المياه العادمة في الري قد يكون له مخاطر صحية محتملة عالية.

الكلمات الدالة: تلوث التربة؛ تلوث المياه؛ مصرف بلبيس. قمح