American-Eurasian J. Agric. & Environ. Sci., 2 (1): 51-61, 2007
ISSN 1818-6769

The Effect of Using Urban Treated and Untreated Effluents on Soil and Agricultural Crops Pollution in Syria (Damascus-Ghouta)

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Abstract: Polluted soil and irrigation water are the most important sources of pollution of agricultural products, with heavy metals mainly field crops and vegetables. A lysimeter experiment cultivated with field crops and vegetables was carried out to study the effect of irrigation with treated urban effluents resulting from Adra plant which receives waste water from Damascus. The heavy metals (As, Cd, Cr and Pb) increased in fruits and leaves of the studied vegetables (Eggplant and Lettuce), as well as in the grain and straw of studied field crops (Wheat and Corn), grown in the concrete lysimeters of 2x1x1m. The pollution caused by irrigation with urban treated effluents was compared with that caused by irrigation with both ground and urban untreated effluents. During the course of the study which extended over two years with two successive seasons per year were grown of the selected four crops, showed the following most important results: A moderate increase of the soil content of heavy metals (As, Cd, Cr and Pb). An increase of the heavy metals contents in the crops components (seeds, fruits and leaves), according to the water quality: (groundwater, urban untreated effluents and urban treated effluents). However, with the exception of Cd, the content of As, Cr and Pb in the crops, remained within the acceptable natural range.

Key words: Urban treated and untreated effluents · urban under ground water · heavy metals · soil and plant tissues

INTRODUCTION

Human and animal wastes had been used to improve agricultural production in the past in several countries. The use of such wastes goes back to 5000 years ago. The use of solid and effluent wastes in the past intended to reduce polluting river water and to economize water use. In Great Britain for example, there is a slang known as rain water for rivers and urban waste water for the soil [1].

In the Arab world Egypt was the first country who used waste effluents and solid wastes in agriculture. It started in 1911 where they used effluent as irrigation water and solid waste as fertilizer in the yellow mountain agricultural area near Cairo.

In Syria, Damascus city waste water drained intro Brada River for a long period of time. The mixture was used for irrigating several crops in Damascus Ghouta without restrictions until 1996. In Aleppo (south Aleppo plain) Homs and Hama provinces, the untreated waste water was used in irrigation for several years back.

Due to the population increase in Damascus province, water shortage started to increase not only for irrigation but also for domestic supply. Hence it became a necessity to look for other sources of irrigation water to reduce the pressure on the fresh water. The urban untreated waste effluents in Damascus province was estimated to be 610 m.m^3/year in 1993 and jumped to 740 m.m^3/year in 2002 [2, 3].

The sewage wastewater in Damascus province consists of sewage effluents, industrial effluents etc., Hamad *et al.* [4] has studied Damascus urban wastewater and found it containing several heavy metals with various concentrations. Chromium has the highest concentration among the studied heavy metals. Several types of pathogenic microbes such as Salmonella, Fecal coliform etc.... Several others [4, 5-9] found similar results. These pathogens and heavy metals can affect both human and animal health [4, 10, 11]. These effects depend on the loads of the waste effluents with different components, which depends "in turn" on local communities' habits and

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the components of different sources of the urban waste effluents. The urban waste effluents contents will affect the crop components irrigated with these effluents, will depend on the type of crop, the soil and the growing season, their rates of accumulation in soils and their movements out of the root zone and plant uptake rates [12-15].

The health and environmental hazards of heavy metals are thoroughly studied by researchers [7, 16-20]. But there is no research work done in Syria about the use of treated urban effluents in irrigation. This study has been carried out to disseminate the safe use of treated urban effluents for irrigating agricultural field crops and Horticultural crops and to provide information to the local communities and decision makers about its proper use. The use of urban treated waste effluents in Syria was studied for the first time in 1998 [21]. This treated effluents used for irrigation of 18000 ha in Damascus Ghouta by local communities. The major objective of this paper is to study the expected effects on the use of such effluents on the quality of local renewable natural resources such as soil, water, crops etc., through the following:

- Chemical characterization of this kind of water such as soluble ions, pH, EC and heavy metals.
- Accumulation of some heavy metals in soils.
- Crop content of heavy metals such as eggplant, wheat, corn and lettuce tissues.
- Monitoring of urban treated waste effluents and their load of chemicals and comparing them with ground water as a control.

MATERIALS AND METHODS

Materials:

A-soils: The soil used for this study is classified by USDA, 1997 soils taxonomy, as calcid soil, collected from Nashabia area 20 km south of Damascus city center [22].

The soils were placed in the lysimeters according to their natural layers in the field. Table 1 shows some chemical properties of the used soil layers.

The soil is clay in texture with average bulk density of 1.11 g cm^{-3} and with real density of 2.66 g cm^{-3}. The saturation moisture % is 58% while the field capacity is 27.5% with wilting points of 8.8%. The available moisture is 18.7% and having saturated hydraulic conductivity of 161.4×10^{-3} cm h^{-1}. The soil is classified as slow infiltration rate soil. Table 1 shows some chemical properties of this soil which classify the soils as alkaline with pH 8.5. Having EC1:5 of 0.2 dS m^{-1}, with average CEC of 17.79 $cmol_c$ kg^{-1}. The soil has an average $CaCO_3$ of 59.80 and 1.29% organic matter. The soil is low in available phosphorus, potassium and nitrogen.

The total content of some heavy metals in the studied soils are presented in Table 2.

Analysis of these heavy metals is found to be within their natural contents of non polluted agricultural soils [5, 16, 23, 24].

B-irrigation water: Three types of irrigation water were used in this study:

- Under ground water with static water level at 120 m depth in the experimental site (T1).
- Treated waste water from Adra treatment plant 25 km east of Damascus city (T2)
- Untreated waste water before entering Adra treatment plant (T3).

From Table 3 we can conclude, that under groundwater contains low potassium values with an average of 0.21 $mmol_c$ l^{-1} and with calcium, magnesium and nitrate contents 5.14 and 3.56 $mmol_c$ l^{-1} and 10.0 mg l^{-1}, respectively. The presence of nitrate is due to heavy rate of nitrogenous fertilizers application to the soil in the last four decades. Nitrate concentrations are higher than in the urban treated effluents and urban waste

Table 1: Chemical properties of soil layers in lysimeters-before cultivation 1998

Depth (cm)	pH (1:25) (H_2O)	pH (1:25) (KCl)	E.C 1:5 dS m^{-1}	Soluble Ions ($mmol_c$ kg^{-1})* Cl^-	$CO_3^=$	HCO_3^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	Av.P mg kg^{-1}	T.N %	Effective $CaCO_3$ %	$CaCO_3$ %	O.M %	C.E.C *$cmol_c$ kg^{-1}
0-15	8.50	7.90	0.19	0.51	0	0.80	0.09	0.17	0.01	0.60	0.50	0.23	0.60	0.05	18.13	62.00	1.35	19.35
16-30	8.50	7.90	0.19	0.70	0	0.95	0.09	0.20	0.02	0.95	0.45	0.24	0.40	0.05	19.00	62.00	1.31	17.39
31-45	8.40	7.90	0.20	0.79	0	1.00	0.09	0.30	0.02	1.10	0.35	0.35	1.36	0.04	18.50	55.00	1.30	17.39
46-60	8.30	7.90	0.20	0.90	0	0.85	0.09	0.26	0.02	1.15	0.35	0.30	0.40	0.04	19.38	59.00	1.30	17.39
61-75	8.50	7.90	0.20	1.10	0	0.85	0.09	0.34	0.02	1.15	0.50	0.37	2.20	0.04	19.00	61.00	1.21	17.39
Average	8.44	7.90	0.20	0.8	0	0.89	0.09	0.25	0.02	0.99	0.43	0.30	0.99	0.04	18.80	59.80	1.29	17.78

*$cmol_c$ kg^{-1} = meq/100 g soil

Table 2: The total content of some heavy metals in the studied soil before cultivation

	(mg kg^{-1})			
Depth (cm)	As	Cd	Cr	Pb
0-15	2.40	0.07	10.5	7.9
16-30	1.9	0.06	11.3	7.6
31-45	1.50	0.05	11.3	6.8
46-60	1.20	0.06	14.1	5.3
61-75	0.90	0.07	16.4	2.6
Average	1.58	0.06	13.0	6.0

Table 3: Some important irrigation water parameters

Type of irrigation water and effluents	pH	E.C dS m^{-1}	Ions (mmol$_c$ l^{-1}) Cl^-	HCO_3^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	(mg l^{-1}) NO_3^-	$NH4^+$	$PO_4^=$	B	BOD
Underground water	7.38	0.86	3.15	6.33	0.13	0.68	0.21	5.14	3.56	10.06	0.05	0.48	0.21	15
Treated	7.40	0.91	3.27	4.96	0.15	1.49	1.28	3.26	2.19	0.40	1.30	8.73	0.63	55
Untreated	7.08	1.07	3.45	6.10	0.17	1.53	1.32	3.95	3.03	0.26	6.41	9.95	0.92	122.5

(*) Every value is an average of 48 analyses (4 seasons× 4 periods)×3 replicates

untreated effluents as shown in Table 3. Ammonium and PO_4 = concentrations are higher in untreated effluents, compared with underground water and urban treated effluents. These values are verified by statistical analysis of the untreated and treated effluents, as example for NH_4^+ (6.41, 1.30 mg l^{-1}), PO_4 = (9.95 and 8.73) mg l^{-1}, for Boron (0.93 and 0.63) mg l^{-1} for untreated and treated waste respectively, in addition both untreated and treated effluents having high values of BOD 122.5 and 55 mg l^{-1} respectively, while the underground water has a value of 15 mg l^{-1}.

C-irrigated crops: Two summer crops and two winter crops were used in this study:

- Summer crops: The summer crops cultivated in the lysimeters were Eggplants (*Solanum melongena*) local variety and corn (*Zea mayes*) Ghouta variety.
- Winter crops: were wheat (*Triticum durum*) Sham 5 variety and Lettuce (*Lactuca sative*) local variety.

Methods of measurements and analysis:

Soil water and effluents chemical analysis: pH was measured in soil water ratio of (1:2.5), effluents and water samples with pH meter (Beckman model). The EC of soil extract was carried out in soil water ratios of 1:5 with conductivity meter (Hach Instrument Company) as well as the urban treated and untreated effluents samples. The soluble ions in soil extracts and in irrigation water as follows. Chloride ion by titration with $AgNO_3$, SO_4 = by turbidity [25], CO_3 = and HCO_3 by titration using H_2SO_4. Sodium and Potassium measured using Flame photometer (Jen way PFp7. UK).

The $CaCO_3$, BOD, B and effective $CaCO_3$ were determined according to the methods in the Methods of soil analysis [26]. The available P was determined according to Olsen and Sommers [27], total Nitrogen by kjeldahl method [28], organic matter according to Methods of soil analysis [29], CEC (Cation exchange capacity) by Na-Acetate method according to Rhoades and Polemio [30]. The nitrate content in irrigation water was determined by phenol disulfonic (C_6 H_6 O_7 S_2) [31]. Ammonium ion determined by Endol blue method [32].

Heavy metals analysis: The total content of Pb, Cr, Cd and As in irrigation water (underground water, urban treated and urban untreated effluents) were analyzed by Atomic absorption GPC 932 AA [33]. The total heavy metals of Pb, Cr, Cd and As in soils were taken at each 15 cm soil depth. Soil samples were air dried, grinded and then passed through 0.5 mm sieve. One gram of the soil sample from each soil depth heated to 800°C for 2 h then the sample digested with 5 ml of 65% HNO_3 and 19 ml of 38% HCl [34] and heated in water bath until almost complete dryness, then the suspension filtered and diluted to 100 ml of double distilled water.

The total heavy metals in plant tissues at the end of the each experiment were determined. Plant tissues were washed with tap water then with double distilled water, dried in an oven at 50°C for 48 h, grinded to very fine

Table 4: Irrigation water treatments of this study

Treatments	Type of irrigation water
T1	Underground water as control
T2	Urban treated waste effluents
T3	Urban untreated waste effluents

Table 5: Average concentrations of Pb, Cr, Cd and As in mg l^{-1} in the irrigation water

	Type of heavy contents in mg l^{-1}			
Type of irrigation water	Pb	Cr	Cd	As
Underground water	0.5 C	0.02 B	0.016 A	0.003 B
urban treated effluents	2.7 B	0.03 AB	0.014 A	0.018 AB
Urban untreated effluents	4.9 A	0.04 A	0.015 A	0.031 A
The upper limit concentrations for irrigation	5.0	0.10	0.01	1.10
$LSD_{0.05}$	0.782	0.017	0.012	0.023

materials, then one gram sample, dry ached at 1000°C for one hour, the dry ached materials were digested with 10 ml concentrated HNO_3 acid with slow heating rate in water bath. The samples then filtered and diluted to 100 ml with distilled water in volumetric flask. The heavy metals (Pb, Cr, Cd and As) were determined with Atomic Absorption GPC 932 AA.

Experimental design: The study was designed according to Complete Randomized Block Design. The experiments consisted of 3 water treatments Table 4 with three replicates.

The number of experimental blocks: Two sets of Lysimeters (18 Lysimeters each) were used in the study. The first set was planted by eggplant and wheat and the second by corn and lettuce. Each set of lysimeters contained 3 replicates with 3 irrigation water treatments and 2 crops (3×3×2 = 18 lysimeters) the area each lysimeter was 2×1 = 2 m^2 and the length 1 m.

RESULTS AND DISCUSSIONS

Heavy metals monitoring in this study:

In irrigation water and effluents: Table 5 shows the average heavy metals contents of different irrigation waters (underground water, urban treated and urban untreated effluents). The heavy metals were Pb, Cr, Cd and As. These average concentrations of these heavy metals are presented in Table 5 during course of this study (1998-2000).

Each value in Table 5 is the average of 48 analyses. The statistical analysis ensures the save use of the treated urban effluents for irrigation concerning heavy metals, noting that these data are the results of continuous analysis of these irrigation water and effluents for two years. These values are lower than the upper limits which are listed by many researchers [6, 7, 17, 20, 35-37].

It is worth to note the followings from Table 5: 1) relatively high content of lead in urban untreated effluents and urban treated effluents (4.9 and 2.7 mg l^{-1}), respectively, 2) relatively high content of Cr (0.04 and 0.03 mg l^{-1}) in urban untreated effluents and urban treated effluents respectively, compared with ground water (0.02 mg l^{-1}). Cadmium concentrations are within the upper limit concentration of WHO standards of all water treatments. Arsenic is below the upper limit of WHO standard. Chromium values for underground, treated urban effluents and untreated urban effluents are below the upper limit of WHO standards. Cadmium values are as an important issue for the water and effluents treatments as well as farmers. Therefore, it should be taken into consideration. Farmers should not use urban untreated effluents because its concentration exceeds the upper limit [20]; moreover, it contains pathogenic microbes.

Monitoring heavy metals in soil: Table 6 shows total heavy metals analysis at various soil depths in Lysimeters after two years of eggplants, wheat, eggplant cultivations irrigated with three types of irrigation water and effluents.

From Table 6 we can note that total average concentrations of lead at the end growing seasons in the soils cultivated with Eggplants and irrigated with the 3 water quality treatments have the following order T3>T2>T1. Lead accumulated in the soil depth 0-45 cm for all treatments. The accumulated of Pb in the irrigated soils is far below the upper limit (200 mg kg^{-1}). Chromium accumulation had the same trend. Cadmium had the same concentrations in all soils irrigated with T1, T2 and T3 treatments. Cadmium concentration is still within the natural range in unpolluted soil. Cadmium moved down to the depth of 46-75 cm from the upper soil depths 0-30. This phenomenon is in the agreements with the finding of Hille *et al.* [38], Abo Rous and Samir [39] and Abdelgawad [40]. Arsenic accumulated at the surface of the soil and in the upper 0-30 cm soil depth is higher than the lower depths. Arsenic concentration is still within the range listed in the literature for unpolluted soil.

Table 7 shows that the total concentrations of Pb,Cd, Cr and As in soils at various soil depth in lettuce-corn lysimeters irrigated with treatments T1,T2 and T3 for the

Table 6: Total concentrations of Pb, Cr, Cd and As at various soil depths after two years of cultivations (1998-2000) with wheat, eggplant

Water treatment	Soil depth cm	Heavy metal concentrations in mg kg^{-1} Pb	Cr	Cd	As
T1	0-15	9.51	13.48	0.086	2.80
	16-30	10.85	12.58	0.089	2.55
	31-45	11.02	11.28	0.173	1.16
	46-60	8.68	11.68	0.086	1.25
	61-75	7.54	12.78	0.216	0.74
Average		9.52 C	12.36	0.13	1.70
T2	0-15	17.61	12.38	0.085	2.73
	16-30	17.33	12.24	0.149	2.12
	31-45	15.85	12.78	0.021	1.48
	46-60	13.03	12.64	0.149	0.62
	61-75	12.63	13.06	0.146	0.45
Average		15.29 B	12.62	0.110	1.48
T3	0-15	29.86	13.76	0.100	3.01
	16-30	29.64	12.62	0.136	2.21
	31-45	24.50	13.02	0.073	1.48
	46-60	24.00	12.69	0.118	0.99
	61-75	21.35	12.56	0.123	0.56
Average		25.87 A	12.93 A	0.110	1.65
Upper limit range		2.0-200	10-150	2-0.01	1.1-80
$LSD_{0.05}$		1.963	NS	NS	NS

T1 = Underground water, T2 = Urban treated effluents, T3 = Urban untreated effluents

Table 7: Total concentrations of Pb, Cr, Cd and As at various soil depths after two years of cultivation (1998-2001) with lettuce and corn

Water treatment	Soil depth cm	Heavy metal concentrations in mg kg^{-1} Pb	Cr	Cd	As
T1	0-15	9.52	13.47	0.108	1.69
	16-30	11.42	15.20	0.112	1.62
	31-45	7.52	17.00	0.104	1.58
	46-60	8.38	17.93	0.096	1.56
	61-75	6.56	15.40	0.080	1.45
Average		8.68 C	15.80	0.100	1.58
T2	0-15	14.91	14.44	0.096	1.82
	16-30	14.33	15.31	0.077	1.74
	31-45	12.91	16.44	0.092	1.67
	46-60	10.44	15.75	0.08	1.54
	61-75	7.81	16.56	0.097	1.88
Average		12.08 B	15.70	0.090	1.73
T3	0-15	24.03	16.23	0.096	2.07
	16-30	22.12	17.26	0.104	2.00
	31-45	18.82	16.74	0.108	1.72
	46-60	14.85	18.46	0.098	1.5
	61-75	11.58	13.31	0.094	1.26
Average		18.28 A	16.40	0.100	1.72
Upper limit range		2.0-200	10-150	0.01-2	1.1-80
$LSD_{0.05}$		1.892	NS	NS	NS

periods (1998-2000), had the order T3>T2>T1 treatments and values of 18.28, 12.08 and 8.68 mg kg^{-1}, respectively. Lead accumulated in the upper 0-45 cm of the soil. The average values of lead concentration in the soils irrigated with T1, T2 and T3 are lower than the upper limit of lead concentration which is 200 mg kg^{-1} according to Who [20]. Chromium accumulation in the soils irrigated with T3 treatments was higher than T1 and T2. Cadmium concentrations in soils irrigated with the three treatments were similar and no clear pattern of its accumulation in soils for T2 and T3 treatments but the pattern was clear in the soil irrigated with T1. Arsenic accumulation in soils irrigated with T3 and T2 treatments were higher than T1 water treatment. Arsenic accumulated in the upper soil 0-45 cm depth. Both Arsenic and cadmium concentrations were higher than the lower polluted soil limits mentioned in literature.

The statistical analysis showed significant differences at 5% level of Pb concentration between irrigation water treatments Table 7. The differences between irrigation treatments were not significant for Cr, Cd and As. The bioavailability of these heavy metals depend on their concentrations in soil solution, which are related to their total concentrations in the solid phases, pH, redox potentials, CEC and other soil properties [41]. For example, the bioavailability of Cr depends on its Oxidation state where Cr^{+6} is very toxic to the living organisms while Cr^{+3} is less toxic. The heavy metals which are inter in organometallic complexes in soils decrease their bioavailability to living organism in soils as well as plant roots, they become slowly available in the soil solution. The bioavailability depends upon biological activities and chemical properties of Rizosphere of plant roots system such as pH, as well as the selectivity of the crop type to absorb certain heavy metals from others.

Plant tissues heavy metals content: In this study, it was found that all the irrigation water treatments caused accumulation of the studied heavy metals in the studied plants tissues. These accumulations in plant tissues increased with growth stages and growing seasons which are in agreement with [3, 5, 42, 43]. Tables 8-11 show the concentration of Pb, Cr, Cd and As in Eggplant Fruits and green materials, what stem and leaves, corn grain and straw and Lettuce leaves respectively. All values are the average of two growing seasons for the three irrigation treatments. Tables 8 & 9 show that Pb, Cr, Cd and As concentrations in green materials of Eggplant and corn are greater than fruits and grains in all treatments including

Table 8: Average total contents of Pb, Cr, Cd and As in eggplant on oven dry weight bases in mg kg^{-1} for different irrigation water treatments

Element	Pb		Cr		Cd		AS	
Normal range	3-20		0.5-2		0.02-0.2		0.02-10	
Toxic level	30-300		5-30		5-30		>10	
Part	Fruits	Green	Fruits	Green	Fruits	Green	Fruits	Green
T1	1.69B	1.86 B	0.95B	1.20C	0.14B	0.18B	0.01B	0.02B
T2	7.56 A	8.33 A	1.95A	4.40B	0.29A	0.31A	0.04A	0.06A
T3	7.75 A	8.28 A	2.01A	4.79A	0.32A	0.34A	0.05A	0.07A
$LSD_{0.05}$	0.578	0.398	0.152	0.264	0.081	0.081	0.015	0.018

Table 9: Average total contents of Pb, Cr, Cd and As in wheat on oven dry weight bases in mg kg^{-1} for different irrigation water treatments

Element	Pb		Cr		Cd		AS	
Normal range	3-20		0.5-2		0.02-0.2		0.02-10	
Toxic level	30-300		5-30		5-30		>10	
Part	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T1	3.44 C	0.29C	0.17C	0.15C	0.28B	0.26B	0.11B	0.08B
T2	5.22B	2.13B	0.57B	0.40B	0.34A	0.29AB	0.18A	0.15A
T3	5.81A	3.09A	0.70A	0.58A	0.35A	0.35A	0.19A	0.17A
$LSD_{0.05}$	0.471	0.161	0.126	0.055	0.086	0.098	0.059	0.04

Table 10: Average total contents of Pb, Cr, Cd and As in corn on oven dry weight bases in mg kg^{-1} for different irrigation water treatments

Element	Pb		Cr		Cd		AS	
Normal range	3-20		0.5-2		0.02-0.2		0.02-10	
Toxic level	30-300		5-30		5-30		>10	
Part	Fruits	Green	Fruits	Green	Fruits	Green	Fruits	Green
T1	2.23C	4.33C	0.12B	0.38B	0.26	0.29	0.00B	0.01C
T2	8.92B	10.68B	0.91A	1.14A	0.28	0.36	0.02A	0.45B
T3	9.57A	12.05A	0.97A	1.24	0.28	0.38	0.02	0.48A
$LSD_{0.05}$	0.263	0.149	0.089	0.154	NS	NS	0.003	0.006

Table 11: Average total contents of Pb, Cr, Cd and As in lettuce on oven dry weight bases in mg kg^{-1} for different irrigation water treatments

Element	Pb	Cr	Cd	AS
Normal range	3-20	0.5-2	0.02-0.2	0.02-10
Toxic level	30-300	5-30	5-30	>10
Part	Leaves	Leaves	Leaves	Leaves
T1	1.83B	0.43B	0.22B	0.17B
T2	3.67A	0.67A	0.34A	0.45A
T3	3.93A	0.75A	0.38A	0.48A
$LSD_{0.05}$	0.261	0.089	0.062	0.054

the control. The concentrations of these metals increase in the order of T3 >T2>T1 water treatments. For As and Pb their concentrations are found to be within their natural ranges in plant tissues for all crops cultivated in this study, for the three irrigation water treatments. Cadmium concentrations in all studied plant tissues are higher than the normal concentration in natural plant tissues, (0.02-0.2 mg kg^{-1}). Chromium concentrations in plant tissues are within its natural conditions except the vegetative parts of Eggplant for treatments T3 and T2 which are higher than normal.

The statistical analysis presented in Tables 8-11 show significant differences in their concentrations in the studied plants for all studied elements between irrigation water treatments except for Cd in corn. In all cases the concentration is the lowest in the treatment irrigation with underground water. That is because the low concentration of these elements in the underground water which is attributed to their adsorption on soil particles during the infiltration process. This means that the underground water can be used safely for irrigation concerning the studied heavy metal.

Heavy metals balance: Table 12 shows the soil water balance for the Lysimeters cultivated with Eggplants, Wheat, Lettuce and Corn. The total water used by crops

Table 12: Water balance for crops used in each study at 80% soil field capacity

Crop	Ave rage initial soil moisture (Si) m^3 ha^{-1}	Average irrigation water added (I) m^3 ha^{-1}	Average amount of water used at the end of growing season to leach the soil (L) m^3 ha^{-1}	Average rainfall (P) m^3 ha^{-1}	Amount of leached water (D) m^3 ha^{-1}	Average final soil moisture (S_f) m^3 ha^{-1}	Average total water used m^3 ha^{-1}	Number of irrigation Norms	Length of growing season (day)
Eggplants (Summer)	1575	9180	1000	0	135	2475	9145	15	144
Wheat (Winter)	1305	4227	1400	695	148	2619	4860	9	182
Corn (Summer)	1476	4875	1400	0	150	2475	5126	8	90
Lettuce (Winter)	1458	3680	1000	695	140	2610	4083	7	146

Table 13: Average balance for Pb, Cr, Cd and As by calculation and analysis in mg/2 m^3 of soils in Lysimeters cultivated with (Wheat and eggplant for two year)

Water treatment	Initial soil contents	Amount added with irrigation water and the added leached water	Amount absorbed by plant tissues	Amount in the leached water	The amount accumulated in soils by calculation	The amount accumulated in soils as determined by analysis	% of differences
AS							
T1	3157	18.97	0.16	0.6	3175	3288	-3
T2		113.81	0.46	2.5	3268	2965	10
T3		196	0.6	3.7	3349	3287	2
Cd							
T1	119.9	101.16	1.26	1.1	219	230	-5
T2		88.52	2.62	1.7	204	234	-14
T3		94.84	3.13	1.8	210	223	-6
Cr							
T1	25974	126.46	8.21	2.60	26090	26279	-1
T2		189.68	26.19	3.30	26134	25180	+ 3
T3		252.91	30.40	3.60	26193	25800	+2
Pb							
T1	25974	126.46	8.21	2.60	26090	26279	-1
T2		189.68	26.19	3.30	26134	25180	+3
T3		252.91	30.40	3.60	26193	25800	+2

* Absorbed by Eggplants + wheat during two growing seasons in mg of plant tissues grown in Lysimeters, T1 = Underground water treatments, T2 = Urban treated effluents, T3 = Urban untreated effluents

were 9145, 4860, 5126, 4083 m^3 ha^{-1} for Eggplants, Wheat, Corn and Lettuce, respectively. The amount of water used for heavy metals balance calculation are the once that were added as irrigation water to Lysimeters.

This section was carried out to compare the analytical and calculated heavy metals concentrations. The balance carried out according to the following:

Soil basic concentrations before cultivation + the amount added with different types of irrigation water- (Amount taken up by plants + amount in the leachate + amount accumulated in the soils after two years of cultivation). This balance was carried out for each type of irrigation water. Tables 13 & 14 show this balance.

From Table 13 we note that the amount of As accumulated by calculation procedures were 3.175, 3.268 and 3.349 g /2 m^3 (the values were converted to g/2 m^2 by dividing the values in Table 13 and 14 by 1000) of soil for the Lysimeter cultivated by Eggplant and wheat for two growing season (wheat + Eggplant + wheat + Eggplant) for T1, T2 and T3 respectively but by analysis, they are 3.288, 2.965 and 3.287 g/2 m^3 soil (Lysimeter). The comparing shows a difference of 3, 10 and 2%. These differences are statistically acceptable. For Cd, the amounts accumulated in soils by calculations in the Lysimeters of (Wheat, Eggplant, Wheat, Eggplant) are 0.219, 0.204 and 0.210 g/2 m^3 soil while with analysis are 0.230, 0.234 and 0.223 g/2 m^3. The differences between them are 5, 14 and 6%, respectively for T1, T2 and T 3 respectively. The values of Cr are 26.09, 26.134 and 26.193 g/2 m^3 by calculations balance while by analysis the

Table 14: Average balance for Pb, Cr, Cd and As by calculation and analysis in mg/2 m^3 of soils in Lysimeters cultivated with (corn and lettuce for two year)

Water treatment	Initial soil contents	Amount added with irrigation water and the added leached water	Amount absorbed by plant tissues	Amount in the leached water	The amount accumulated in soils by calculation	The amount accumulated in soils as determined by analysis	% of differences
AS							
T1	3157	13.15	0.57	0.40	3169	2880	+ 10
T2		78.88	2.02	2.80	3231	3454	-6
T3		135.84	2.06	4.00	3287	3428	-4
Cd							
T1	119.90	70.11	4.98	0.90	184	190	-3
T2		61.35	8.10	1.30	172	176	-2
T3		65.73	7.14	1.80	177	183	-3
Cr							
T1	25974	87.64	7.94	2.60	26051	28914	-10
T2		131.46	30.70	4.40	26070	31232	-13
T3		175.28	29.17	4.90	26115	26810	-3
Pb							
T1	11988	2191.00	92.33	0.30	14086	15884	-13
T2		11831.00	284.20	1.70	23533	24110	-2
T3		21910.00	263.61	6.70	33628	36478	-8

*Absorbed by Lettuce and Corn during two growing seasons in mg of plant tissues grown in Lysimeters, T1 = Underground water treatments, T2 = Urban treated effluents, T3 = Urban untreated effluents

values are 26.279, 25.180 and 25.800 g/2 m^3. The differences are within 1, 3 and 2% above or below 100% which are really good for T1, T2 and T3. For Pb, the values by calculations are 15.132, 28.98 and 43.511 g/2 m^3 but by analysis, the values are 17.43, 30.500 and 51.606 g/2 m^3 for T1, T2 and T3 respectively. The differences between calculated and analysis are 13, 5 and 16% for T1, T2 and T3 respectively.

For the Lysimeters which were cultivated by Corn-Lettuce-Corn-Lettuce (Table 14) the concentrations of As by calculation for the three irrigation treatments were 3.169, 3.231 and 3.287 g/2 m^3 soil while by analysis are 2.880, 3.454 and 3.428 g/2 m^3 soil for the T1, T2 and T3 treatments respectively. In general they are comparable to each other. For Cd the concentrations by calculation were 0.184, 0.172 and 0.177 g/2 m^2 while by analysis are 0.190, 0.176 and 0.183 g/2 m^3 soil for T1, T2 and T3 respectively. The differences between the cultivated and the analyzed are within 3%. Chromium concentrations by calculations were 26.051, 26.070 and 26.115; while by analysis were 28.914, 31.232 and 26.810 g/2 m^3 soil for T1, T2 and T3 respectively. The difference range between 3 and 17%. Lead concentrations by calculations were 14.086, 23.533 and 33.628 and by analysis are 15.884, 24.110 and 36.478 g/2 m^3 soil for T1, T2 and T3 respectively. In general, there is a good agreement in heavy metals balance between calculated and analyzed.

CONCLUSIONS

The conclusions, which can be drawn from this study, are:

- The lead concentrations in soil increases with irrigation water and effluents added continuously. The accumulations mainly concentrated at the first soil depth (root zone 0-45 cm soil depth). This will cause in the future to more accumulation in this zone and bioavailability of heavy metals will increase with its rate of accumulation, this will lead to increase in its concentration in plant tissues. The rates of accumulations are in urban untreated effluents higher than the treated once respectively.
- There is similarity in the accumulations behaviors of As and Pb in soils. There are differences in their rates of accumulation in soils among different water and effluents used for irrigation in order of their increase, in their concentrations, urban waste untreated>urban treated waste effluents> underground water.
- There are no differences in the rate of Cd accumulations in soils due to different irrigation water and effluents used and are in order of untreated>treated>underground. This conclusion is confirmed with statistical analysis as shown before;

this is due to the quite similar concentrations of Cadmium in these irrigation waters and effluents.

- Chromium metal is progressly accumulated in soils; this accumulation is due to its concentrations in different water and effluents types in irrigation water. Its rate of accumulation in soils is higher in urban untreated effluents>urban treated effluents> underground water. Tanneries factories waste is the source of cr in the damascus urban waste effluents...
- The concentrations of Pb, Cr, Cd and As in plant tissues are higher in the treatments irrigated with urban untreated effluents>treated>ground water, in all plant tissues studied in this study, the concentration of Cd are higher than the upper normal concentrations in plant tissues as shown in Table 10 (0.2-0.02) mg kg^{-1}. For Pb, Cr and As are as well higher than the normal lower values of these metal concentrations in plant tissues respectively as shown in Table 10, but they are less than their toxic (values), for Cr its concentration is higher than the normal concentrations in plant tissues in Eggplant, (green cover) but not in fruits for both the treatments of treated and untreated waste effluents and still lower than its toxicity limits. Other elements (Pb, As) their concentrations are within the limit of normal concentrations in plant tissues.
- Based on the WHO, FAO, others international standards and Syrian standards of using treated waste effluents and the statistical analysis for monitoring such effluents in Damascus treatment plant, this effluent can be used safely for irrigation as far as the heavy metals studied but continuous monitoring of these elements and others is needed.
- It is important to follow up the concentrations of Cd, Pb in the treated effluents, because their concentrations are close to the upper limit standards of its irrigation water use especially Cd the sources of Cr, are tanneries factories effluents. These effluents should be well treated before drain it to the sewage drainage line.
- The heavy metals balance showed that the accumulations of heavy metals by calculations or analyses in soils are comparable to each other.
- In Syria, it is necessary to apply the law of the treated use in rigid way and rigid procedures in monitoring the qualities of treated effluents and its use. As well as long term effect should be studied.

ACKNOWLEDGMENTS

The Authors are grateful to professor Albert L. page from University of California at riverside department of environmental science and Dr Awadis Arsalan from ACSAD for reading the manuscript and providing us with their valuable comments

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