Coupling Sustainable Sanitation and Groundwater Protection, October 14 - 17, 2008
Hannover, Germany

Cairo East Bank Effluent Re-Use Study 4-Monitoring Of Groundwater Contamination As Affected By Crop Irrigation With Secondary Treated Wastewater

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Abstract:

Large scale field trials were conducted in fertile soil and desert (virgin) soil to evaluate the effect of irrigation with secondary treated wastewater from two wastewater treatment plants in Cairo on biological and chemical properties of soil and groundwater. Groundwater monitoring wells were installed in and around the experimental soil sites.

Considerable amounts of macronutrients (NPK) were applied to the grown crops through the treated wastewater irrigation: N (19-79%), P (23-181%) and K (85-357%) of the recommended fertilizer rates according to the crop and the experimental site.

Groundwater samples which were examined for the presence of pathogenic bacteria (salmonella), faecal coliform bacteria and helminth ova and10-57% of the samples from each well contained salmonella

The numbers of faecal coliforms were in the range 10^2-10^3 MPN per 100 mL. Small numbers of parasite ova were also found in the majority of wells.

The groundwater was of poor quality, and would be unsuitable for potable or irrigation purposes.

Methods:

The paper is a part of a large study entitled the "**Cairo East Bank Effluent Re-use Study**". The client is the **Cairo Wastewater Organization (CWO)** and the study is partially funded by the **Kuwait Fund for Arab Economic Develop-ment (KFAED)**. The study was implemented by a joint venture consortium of **Montgomery, Watson, Gibb Interna-tional, and some other Arab companies**.

Large scale field trials were carried out in summer 2000 and winter of 2000-2001 seasons in two sites located about 20 km north east of Cairo. The first site is located inside Gabal El Asfar farm, the soil is rich in organic matter and fertile and can be classified as loamy-sandy soil. The same area was chosen in the second site and located inside El Berka wastewater treatment plant; the soil is gravelly sand and could be classified as virgin soil. This work will focus on the virgin soil trial site

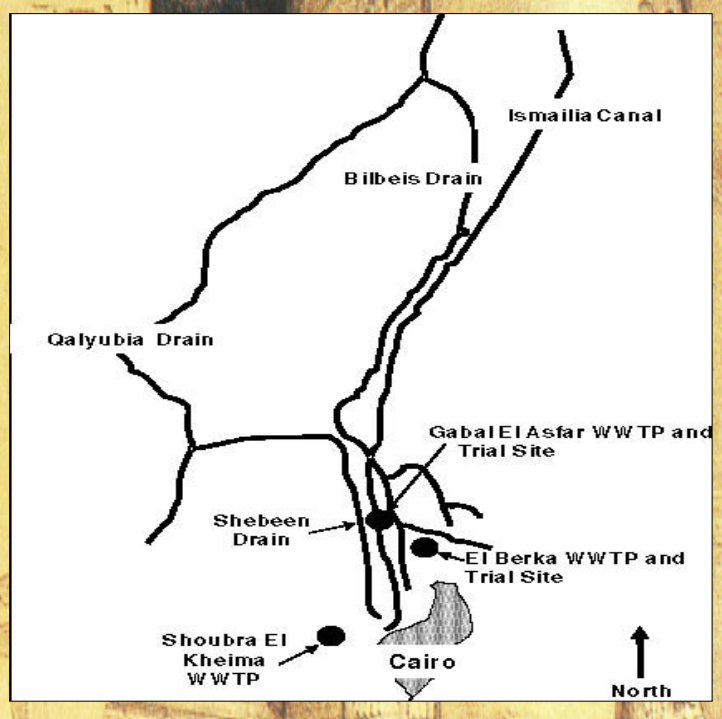


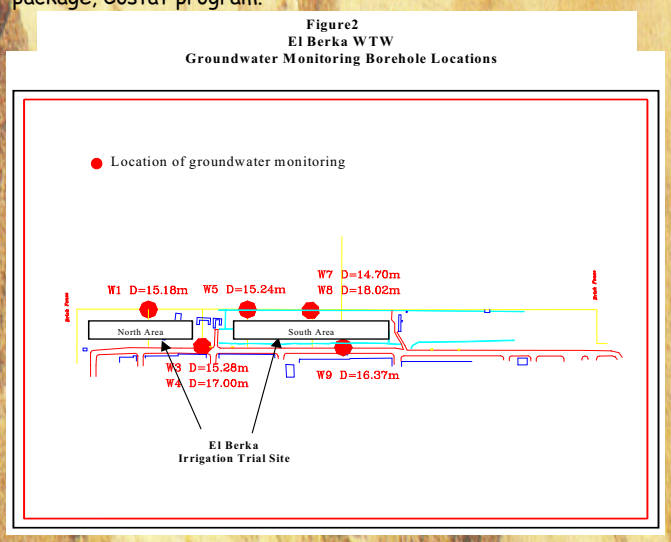
Fig. 1. Schematic location plan showing Trial Sites and East Bank WWTPs.

Crop selection included range of food, fodder and industrial (fiber and oil) crops according to WHO (1989). For summer season 2000, Cotton, soybean maize and sunflower were grown. In winter season 2000-2001, wheat , fababean, lupine and canola) were grown. Surface drip and sprin-kler irrigation systems were used. Sprinkler irrigation was used for soybean and canola; drip irrigation for maize, sunflower, lupin and fababean, as well as surface irrigation for cotton and wheat.

The sampling program included wastewater and groundwater quality. Treated wastewaters were analysed ac-cording to APHA (1992). All samples were analysed according to the common standard methods.

Groundwater monitoring wells were installed by the Research Institute for Groundwater (RIGW). At El Berka, seven wells were installed around the trial area, five to the top of the water table (mean depth 15.4 m) and two deeper wells (mean depth 17.5 m). Samples of groundwater were taken from all of the monitoring wells using a submersible pump. The samples were analysed for a range of chemical (pH, Total NPK and heavy metals and microbiological (salmonella and total coliform counts) parameters according to AFHA (1992). The obtained results were subjected to the proper statistical analysis using Cohort2 package, Costat program.

Figure2
El Berka WTW
Groundwater Monitoring Borehole Locations



RESULTS:

Treated wastewater quality:

Final wastewater samples collected over the period of the tri-als were monthly routinely analysed for nutrients and heavy metals. The results showed that wastewater charactrestics was within the acceptable range for reuse, normally according to the Egyptian decree for wastewater reuse (Decree 44, 2000).

Table 1 Mean concentrations of treated wastewater irrigatedchemistry and microbiology from El Berka WWTPs.

Parameters	Mean	Min.	Max.	n	CV%
pH	7.78	7.65	7.86	9	0.8
Total N	12.8	7.4	18.7	25	23.9
Total P	3.4	1.2	5.3	26	29.3
K	13.8	8.3	24.1	27	23.3
Fe	0.577	0.064	0.98	13	54.8
Mn	0.115	0.01	0.32	11	67.4
Cr	0.027	0.006	0.087	11	120
Ni	0.039	0.007	0.082	11	68.7
Zn	0.094	0.011	0.18	11	67.7
Cu	0.049	0.014	0.093	11	56.2
Cd	<0.005	<0.005	<0.005	13	-
Pb	0.079	0.031	0.13	13	31.7
Mo	<0.01	<0.01	<0.01	11	-
Co	<0.005	<0.005	<0.005	11	-
Salmonella	1.8	1	2	26	26.1
F. coliforms	35	3	82	24	71.7
Helminth	49	5	202	25	103.1

Units: All determinands in mg/L except: EC (dS/m); salmonella qualitative range 0 - absent, 1 - low, 3 - high; faecal coliform bacteria 105 MPN/100 mL; helminth ova/L

Groundwater quality:

The mean analytical results of groundwater monitoring from Each Well at El Berka, after three crop cycles irrigation presented in (Table 2).The overall mean concentrations of groundwater chemistry and microbiology are shown in Table 3. The data showed considerable spatial and temporal variation in the groundwater .There was no discernible rela-tionship between well location and irrigation of treated wastewater in the trials. Sodium and chloride ion concentrations were relatively high . Heavy metal concentrations in the groundwater were small.

The groundwater samples which have been examined for the presence of pathogenic bacteria (salmonella), faecal coliform bacteria and helminth ova indicated that the groundwater was contaminated by secondary treated wastewater irrigation. About 10-57% of the samples from each well contained salmonella. The numbers of faecal coliforms were in the range 10^2-10^3 MPN/100mL. Small numbers of parasite ova were also found in the majority of wells. It is interesting that all of the sampling wells showed declining concentrations of nitrate leached from April but increasing again from August, reaching similar levels in October to those at the start of the monitoring program. This could represent a seasonal effect of nitrate leaching following the peak irrigation period, with a lag phase before the nitrate reaches the groundwater.

Table 2 Mean Analytical Results of Groundwater Monitoring from Each Well at El Berka, After three Crop Cycles irrigation

Parameters	Units	WB1	WB3(s)	WB4(d)	WB5	WB8(d)	WB9
BOD	mg/l	4	5	7	5	3	8
COD	mg/l	6	7	9	7	5	11
TSS	mg/l	21	25	26	27	27	31
TDS	mg/l	1835	2033	980	1120	1160	1335
EC	dS/m	2.6	2.8	1.3	1.6	1.6	1.8
SAR		8.6	9.2	4.8	5.6	5.7	6.4
Total N	mg/l	3.7	3.3	4.3	2.6	3.5	4.9
Total P	mg/l	0.41	0.29	<0.2	<0.2	0.35	0.46
K	mg/l	20	21	13	14	14	18
Fe	mg/l	0.713	0.588	0.18	0.327	0.546	0.323
Zn	mg/l	0.165	0.201	0.206	0.272	0.24	0.173
Cu	mg/l	0.13	0.096	0.203	0.137	0.201	0.23
Cd	mg/l	0.009	<0.0005	<0.0005	<0.0005	<0.0005	0.003
Hg	mg/l	ND	ND	ND	ND	ND	ND
Pb	mg/l	0.055	0.082	0.047	0.021	<0.005	0.009
Salmonella	% positive	75	0	50	25	0	75
Faecal Coliforms	CFU/100ml	1803	343	5525	6888	515	240
Helminths	Eggs/l	2.3	1	3	1.5	0	0

n = 4; ND = not determined; WB3/WB4 are paired wells; (s) = shallow; (d) = deep

Table 3. Overall mean concentrations of groundwater chemistry and microbiology at El Berka.

Parameter	Mean of all wells	Minimum	Maximum	Parameter	Mean of all wells	Minimum	Maximum
Biological oxygen demand (BOD)	4	2	6	Ca	215	161	320
Chemical oxygen demand (COD)	13.4	3.6	130	Na	457	387	1045
Total soluble solids (TSS)	26.3	21	31.3	Mg	35.9	32.9	50.1
Total dissolved solids (TDS)	1674	1247	3063	B	2.67	1.84	3.49
EC	2.34	1.87	2.99	Fe	0.324	0.019	0.833
Sodium adsorption ratio (SAR)	6.7	6.4	6.9	Mn	0.036	0.029	0.05
HCO3	5.94	4.81	7.4	Cr	0.016	0.003	0.027
Total Kjeldahl nitrogen (TKN)	3.85	3.53	4.4	Ni	0.009	0.006	0.02
NH3	1.79	1.6	1.98	Zn	0.315	0.095	0.7
NO2	0.04	0.04	0.04	Cu	0.165	0.005	0.505
NO3	72.7	44.1	127.3	Cd	0.013	0.006	0.015
SO4	2410	1165	3821	Pb	0.037	0.006	0.099
Cl	413	316	482	Salmonella	32	0	100
PO4	1.76	0.22	8.5	F. coliforms	1440	0	4158
K	8.72	2.3	20	Helminths	0.5	0	3

Units: All determinands in mg/L except: EC (dS/m); salmonella % positive samples; faecal coliforms MPN/100 mL; helminth

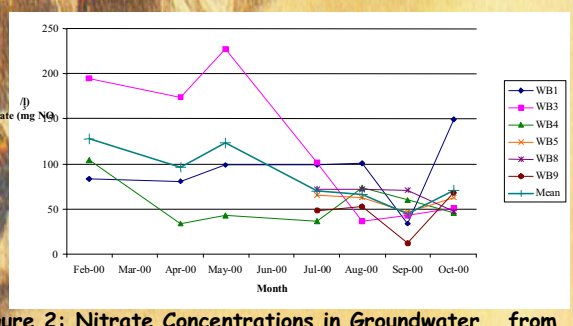


Figure 2: Nitrate Concentrations in Groundwater from each Monitoring Well at the experimental site

Conclusion:

The general chemistry of the treated wastewater does not impose any constraints on the types of crops that may be grown or the types of soil to which it may be applied. Beneficial additions of NPK to the grown crops were evident

However, microbial and parasitic levels indicate that chlorination at levels to achieve faecal coliform compliance does not significantly reduce viable nematode numbers. Consequently, additional treatment of this treated wastewater (such as by UV, sand filters or lagooning) would be necessary to achieve compliance.

Evaluating the effect of irrigation with secondary treated wastewater is important because the target and candidated areas of wastewater reuse are desert soils, therefore it is essential to continue monitoring of drinking water and other water resources from an environmental scene