Safe Reuse of Treated Wastewater for Inedible Seed Production

El-Araby A[1]., Wasif E.,[2] and Mehawed H[2].

Abstract

Four years of successful environmental wastewater treatment at Sadat Pilot Site, western desert of Egypt, safe production of inedible seeds was realized. Mixed domestic and industrial wastewater was treated through, oxidation pond; polishing pond then constructed gravel wetland cultivated with different types of water reeds. Three types of inedible seeds were produced and analyzed for heavy metal content. Vegetable seeds of Onion, Celery and red Turnip, cut flowers; Chrysanthemum and, potato marigold. Decorative plants; Coreopsis, Alyssum and Santorum were selected after several trials, of successful production under local environmental conditions of soil, water and climatic norms prevailing in the area. Heavy metal contents of the produced seed indicated safe use of those seeds for producing safe crops if cultivated in other areas. Dilution of heavy metal pollutants was calculated and proves safe use of the produced seeds. Water quality of primary treated wastewater expressed as EC of 1.58 ds/m, pH of 7.92 and BOD of 89.0 while after tertiary treated wastewater (wetland) EC of 2.70 ds/m, pH of 8.6 and BOD of 16.0, heavy metal content, i.e. Cd, Pb, were 0.02 and 0.27 ppm respectively in primary treated, while 0.01, and 0.16 ppm respectively in the tertiary treated, wastewater. On the other hand heavy metal content i.e. Cd, Pb, Ni in the produced seeds were 0.00, 0.00 and 50.90 in Onion seeds and were 0.00, 0.50 and 30.00 ppm in Alyssum seeds while 0.00, 2.35 and 12.50 ppm in Celery respectively. .

Keywords wastewater reuse, inedible seeds, arid climate.

INTRODUCTION

Water has been a scarce resource in the Middle East since early civilizations. Water resource allocation continues to be the most urgent and pressing issue for the region. Today, water shortage in the Middle East has forced countries to reuse treated wastewater for agriculture, industry, recreation and to recharge aquifers (Asano & Mills, 1990). Due to the increasing demand for water use in the arid region wastewater reuse is recognized as one of the rising alternative water resources.

Wastewater has been extensively reused as a source of irrigation water for centuries in water shortage countries, since irrigation water does not usually require high grade water quality compared to drinking water, (Asano and Levine. 1996).

Reuse of reclaimed water for irrigation enhances agricultural productivity: it provides water and nutrients, and improve crop yields However; it requires public health protection, appropriate wastewater treatment technology, treatment reliability, water management and public acceptance and participation. It must also be economically and financially viable, (Bahri, 1999). Various physical, biological and chemical treatment processes that can be applied in wastewater treatment have been reviewed by (APHA 1995), In addition, the sustainability of wastewater for irrigation is determined by the amount and kind of salts present as well as its potentials to causing problems. Various soils and cropping problems were reported when using wastewater.

1,Professor of Soil Sci, Ain Shams Univesity 2, ENRI, ARC, Egypt.

Those problems related to usage of poor quality wastewater include salinity, permeability and toxicity among others. While the wastewater reuse for agriculture has the advantage of securing alternative water resources with economically, high concentration of nutrient and other constituents may bring adverse effects on environment soils, crops and irrigation water management, (Shainberg and Oster, 1978). The most significant wastewater reuse takes place in arid region, where other sources of water are not enough, (Harovy, 1997). High levels of nitrogen in wastewater may result in nitrate pollution of groundwater sources used for drinking, which could lead to adverse health effects. Accumulation of heavy metals in soils and its uptake by plants is another risk associated with wastewater irrigation (Khouri, Kalbermatten and Bartone 1994). Distribution of wastewater on the soil may be repeated for at least 3 – 5 years without encountering significant problems. (Cox L. etal. 1997). The removal of nitrogen was more effective than that of phosphorus in the agal ponds studied by LI et al., (1991) with efficiencies up to 99.3 % for nitrogen and 48.1 % for total phosphorus. Health risks associated with the agricultural application of reclaimed wastewater involve farmers / agricultural workers and consumers (Crook, 1991). Other environmental concerns are also important, particularly the fate of toxic substances (such as heavy metals) or Endocrine Disrupting Substances. The treatment methods alone (including or not effluent disinfection) or in combination with the proper irrigation techniques should eliminate the health and environmental risks involved.

In Egypt late of 1990's the ministry of agricultural issued a decree forpedden the reuse of reclaimed wastewater for irrigation of food and fiber crops, but only for wood trees production. Therefore the aim of this research is evaluate the safety reuse of the reclaimed wastewater for producing some inedible seeds as a more economic alternative rather than poor wood trees production under arid climatic conditions in the western desert of Egypt.

MATERIAL AND METHODS

The research was carried out in the desert adjacent to Sadat city, Egypt using treated wastewater to produced inedible seed production. The WHO, 1989 code of irrigation water quality of was considered in addition to the Egyptian code.

Six crops have been selected for seed production; Vegetables seed crops (onion and celery), out door plant species (Coreopsis and alyssum) and cut flowers species (Chrysanthemum and potato marigold). Two types of treated wastewater were used; polishing pond (secondary treated) and wetland (tertiary treated) effluents Fresh under ground water was used as control. Table (1) Each plot area was 70 m^2; each crop cultivated in seven rows. The length of each row is 10 m and spacing between rows is 1 m. Each treatment was replicated three times and arranged to comply with the statistical design of randomized complete block design with three treatments; polishing, wetland effluents and freshwater used for irrigation as a control. Seeds were cultivated for two growing winter seasons of 2004 / 2005 and 2005 / 2006 all types of seeds were planted in a soil irrigated with wastewater for 5 years, some physical and chemical soil analyses are shown in Table 2&3 at 50 cm spacing and 1 meter raw spacing. Therefore the number of plants per plot was 140. The plantation was completed through 10^{th} to 20^{th} 2004 and around the same dates of 2005of October. All the experimental plots received only organic manure at soil preparation stage with about 1/2 liter per plant along the dripper. Standard agronomic practices were applied for irrigation and plant protection during the two growing the spring and the summers of 2005 and 2006. Seeds were hand picked, sun dried and manually cleaned. Seed yield was determined as grams per meter of irrigation pipes, germination tested were performed in Petry dishes. Heavy metals contents of some seeds were determined using standard chemical analyses method using Atomic Adsorption Spectrophotometer, Model Perken Elmer 3110.

Some data were analyzed, for Onion and Coreopsis through ANOVA to determine the effect of treatments and Tukey's studentized range (HSD) tests were performed to determined the statistical significance of the differenced between means of treatment.

Table (1): Wastewater analyses before and after reclamation treatments. Date of sampling

Parameters	**Inlet** *(oxidation pond effluents)*	**Polishing pond Effluent**	**Wetland bed Effluent**	**Fresh water**
PH unit	7.23	7.94	6.42	7.91
Total Alkalinity mg/L	265	310	340	358
Total suspended solids mg/L	105.5	77.1	50.1	ND
Total dissolved solids (TDS) mg/L	954	1022	505	ND
Biochemical oxygen demand (BOD_5) mg/L	80.8	32.3	16.7	ND
Chemical oxygen demand (COD) mg/L	166.5	105.4	45.6	ND
Ammonia-Nitrogen (NH_4-N) mg/L	3.2	2.6	4.91	ND
Nitrate-Nitrogen (NO_3-N) mg/L	3.3	1.85	0.32	ND
Total phosphorus(T-P)mg/L	8.9	3.9	3.7	ND
EC dS/m	1.43	1.6	2.6	0.69
Cl me/l	6.7	8.1	8.8	3.6
Fe *ppm*	6.75	8.8	7.95	0.0
Cu *ppm*	1.66	1.48	1.20	0.0
Zn *ppm*	0.0	0.0	0.0	0.0
Mn *ppm*	1.30	0.2	0.62	0.0
Cd *ppm*	0.0	0.0	0.0	0.0
Pb *ppm*	0.80	0.38	0.20	0.0
Ca me/L	6.3	8.1	8.95	8.19
K me/L	0.8	0.9	0.91	0.31
Na me/L	7.8	7.6	10.0	7.9
HCO_3 me/L	8.91	7.4	8.73	5.3
Mg me/L	2.1	2.0	2.3	3.5

Table (2) Effect of reused wastewater on some top soil characteristics.

Profile	Soil depth(cm)	pH	EC (dS/m) 1:2	Soluble cations and anions (meq/l)					
				Ca	Mg	Na	K	HCO_3	Cl
Wet.	(0-10)	9.9	1.08	2.3	1.28	5.65	0.85	2.94	5.22
	(10-20)	9.8	0.55	1.17	0.65	2.88	0.43	2.8	1.8
	(20-40)	10.1	0.39	0.83	0.46	2.04	0.31	2.11	1.08
Fresh	(0-10)	8.5	3.06	6.52	3.62	16	1.02	1.54	6.19
	(10-20)	8.4	1.34	2.85	1.59	7.01	1.06	0.84	3.96
	(20-40)	8.56	0.77	1.64	0.91	4.03	0.61	1.18	1.08
Pol.	(0-10)	9.71	0.96	1.78	0.45	4.84	0.38	1.48	3.76
	(10-20)	9.6	0.74	1.58	0.88	3.87	0.58	1.43	2.34
	(20-40)	8.6	1.56	3.32	1.85	8.16	1.23	0.73	1.35

RESALT AND DESCUTION

The main objective of this research is to delete the environmental wastes to reduce the risk of the concentration of the environmental pollutants particularly the heavy metals. Meanwhile to realize an economically feasible reuse of the reclaimed wastewater in agriculture production of inedible seeds is a good and economic agricultural activity if it is technically viable and safe regarding the heavy metals concentration not necessarily in the seeds but in the propagated plants there after. This experiment was carried out in a soil received reclaimed wastewater for irrigation along the past five year. The seed yield and germination rates were determined for the tested plants of various types, namely Onion, Celery and red turnip (Vegetables), Chrysanthemum and Potato marigold (cut flower) and Coreopsis, Alyssum and Santorum (decorative plants). Table (4) indicated the average seed yield of the tow growing season 04/05 and 05/06, the average germination rates for some of the tested crops were 75% for onion, 40% for Celery, 74% for Coreopsis and 31% for chrysanthemum, but low for other seeds, therefore the statistical analysis was performed only for Onion and Coreopsis. Data indicated clearly that the seed yield of most tested plants was affected by the irrigation water quality and also with soil characteristics. However some plants such as Coreopsis produce similar yield. Therefore two crops were selected for statistical analysis using ANOVA. Data of the statistical analysis indicated that significant differences in the seed yield production for Onion, F value 0.0015, however the germination rate was not affected significantly due to the prolonged irrigation by reclaimed wastewater, F value = 0.3011.

Table (4): Average of Seed Yield

Crop Type	Seed Yield of 04/05 g/m* for different treatment			Seed Yield of 05/06 g/m for different treatment		
	Fresh	Wetland	polishing	Fresh	Wetland	polishing
Onion	7.14	3.33	5.40	5.90	4.10	4.17
Celery	8.00	4.00	5.40	6.00	4.70	5.00
Coreopsis	16.13	18.20	20.00	12.5	22.0	18.18
Santorum	11.11	13.50	13.00	8.30	10.4	15.2
Chrysanthemum	40.00	58.30	48.60	39.4	48.15	43.8
Mary Gold	33.33	44.44	44.12	33.3	44.0	43.7

* g/m gram per meter of drip line

Regarding the coreopsis, both seed yield and germination rates were not affected significantly due to (F values 0.1272 and 0.0830), Peratlta et al (2000) indicated that seed germination of alfa alfa is seriously affected by concentration of Cu, Cd, Cr and Ni. Some other concentration has no or stimulated effect on seed germination and growth. It seems that Onion seed production affected negatively by the levels of heavy metals in the top soil. Kuo et al (1983). Other soil characteristics may also influenced the growth and seed yield and quality such as the soil salinity which increased due to the prolonged use of reclaimed wastewater in irrigation. Quality of reclaimed wastewater used for irrigation was the major factor affect the soil characteristics of the top soil, crop growth as well as the quality of produced seeds. However the economic value of the produced seeds still more better than other uses such as low quality wood trees. Seed quality was almost the same in both plots irrigated with wetland and polishing effluents however much better quality seeds produced using fresh water for irrigation as indicated from the weight of the same number of seeds.

Table (5): Heavy metal analyses for soil of Wetland, Polishing and fresh experimental plots.

Cd	Pb	Ni	Cu	Zn	Mn	Fe	Soil depth(cm)	
g/Kg soil								
-	2.28	1.59	7.53	8.53	11.90	17.67	0-10	Wetland
-	2.13	1.24	7.48	8.18	9.63	17.89	10-20	
-	1.05	0.92	4.13	5.53	8.63	13.43	20-40	
-	0.96	0.73	2.11	3.31	4.80	14.87	40-80	
-	5.36	3.25	13.89	15.18	21.23	29.13	0-10	Polishing
-	5.28	3.12	13.87	12.74	19.64	26.24	10-20	
-	3.24	2.81	8.23	9.31	17.35	25.76	20-40	
-	2.21	2.04	5.62	5.68	11.78	22.39	40-80	
-	0.00	0.19	0.23	0.94	0.86	8.54	0-10	Fresh
-	0.00	0.15	0.24	0.44	0.56	8.41	10-30	
-	0.00	0.11	0.15	0.20	0.37	6.74	30-60	
-	0.00	0.06	0.09	0.12	0.98	4.48	60-90	

Data of heavy metals analysis of top soil layers of the experimental plots reveal that heavy metals contents of the experimental site soils are below the standard limits of both Holland, England and Germany as reported in the science, technology and environment agency, Ho Chi Minh City., Report of environmental activity (2000).
Table (6) heavy metal contents in produced plant seeds

	Type of plant	Heavy metal							
		Fe	Mn	Zn	Cu	Pb	Cd	Ni	Co
Fresh	onion	60	15.0	0	0	0	0	10.0	3.5
	celery	274	33.5	13.35	5.0	1.35	0	2.5	10.0
	coreopsis	250	4.7	3.2	4.0	0	0	2.0	2.5
	Alyssum	650	18.0	12.0	1.5	0	0.50	10.0	2.0
	chrysanthemum	ND	ND	ND	ND	ND	ND	ND	ND
	potato marigold	ND	ND	ND	ND	ND	ND	ND	ND
Wetland	onion	57.2	16.2	13.4	2.75	0	0	30.0	4.5
	celery	860	18.0	6.75	4.3	1.80	0	12.0	12.0
	coreopsis	370	5.5	3.1	4.0	0	0	2.5	3.0
	Alyssum	1560	38.5	18.0	2.6	0.95	0.55	35.25	5.0
	chrysanthemum	119.5	12.4	8.0	4.9	4.0	0	0.15	3.0
	potato marigold	105	49	19.0	4.2	2.5	0.40	2.1	ND
polishing	onion	82.3	17.5	16.20	4.9	3.75	0	40.0	4.5
	celery	1950	25.0	9.8	7.8	3.5	0	25.0	15.0
	coreopsis	760	15.0	10.0	5.0	0	0	4.0	5.0
	Alyssum	4200	20.0	20.0	4.6	1.30	0.56	33.4	4.0
	chrysanthemum	140.0	10.5	13.4	5.0	3.4	0	35.0	3.5
	potato marigold	115	16	13.2	5.0	4.7	0.35	5.0	4.0

However the produced seeds contain significant amounts of heavy metals as shown in table (6),. This may be attributed to the heavy metals in the reclaimed wastewater used for irrigation as indicated in table (1). The amount of heavy metals assimilated by plants dose not differ due to plant species, also the soil total content of heavy metals cannot be used as an explicit criterion for ecological evaluation of soils with regard to their exploitation for agricultural activities, Penka, et al (2004). It can be concluded that the quality of irrigation water is the most effective parameters determining the sees yield and quality. Therefore the produced seed should not propagated using the same quality water for the final stage for producing edible product. In this case very environmental safe dilution will realized due to the following calculation i.e for Onion seeds produced using polluted wastewater.

Table (7): Seed weight: average weigh of seed of some tested plants.

Type	No. of seeds	Weight/ g		
		Wetland	Polishing	Fresh
Onion	100	0.43	0.45	0.65
Celery	1000	0.48	0.50	0.57
Coreopsis	1000	0.25	0.30	0.36
Chrysanthemum	500	1.29	1.20	2.00

One seed contain 40.0 ppm of Ni if cultivated and irrigated with good quality water then produced an Onion pulp of 100g. One seed weights 0.0043g, as shown in Table (7) provided that all the Ni contaminate will accumulate in the onion pulp then the

40.0ppm concentration will diluted to 0.0043x 40/100 means that the Ni concentration the produced Onion pulp is $72x10^{-6}$ ppm. For the other seed produced the contaminant concentration will be much less as the seed Wight is extremely low. The germination rates were affected significantly with the irrigation water quality therefore it can be also concluded that crop selection tests should be performed using seed germination test as an explicit criterion. Following this sequence safe inedible seed production can be realized using treated wastewater for irrigation.

References:

Asano, T., & Mills, R.A. (1990, January). Planning and analysis for water reuse projects, Journal American Water Works Association, 38-47.

Asano, T. and A.D. Levine, 1996 Wastewater reclamation, recycling and reuse: past, present, and future. Wat. Sci. Tech. 33 (10-11): 1-14.

APHA(1995): Standard method for the examination of water and wastewater. Washington DC.

Bahri, A. (1999). Wastewater reclamation and reuse in Tunisis. In Wastewater Reclamation and Reuse Ed. By T. Asano, Technomic Inc., 877-916.

Bokil. S. D. and John. U. L. (1981) treatment of domestic wastewater flocculating algal bacterial system. Indian J. Environ. Health 23. 142-146

Cox, L., R. Celis, M. C. Hermosin, A. Becker, and J. Cornejo. 1997. Porosity and herbicide leaching in soils amended with olive-oil wastewater. Agriculture Ecosystem & Environment: 151-161.

Crook J. "Quality criteria for reclaimed water" Wet. Sci. Tech., 24, 9, 109-121 (1991). EPA "Land application of municipal sludge" process design manual EPA 625/1-83-016 (1983).

Haruvy, N. 1997. Agricultural reuse of wastewater: Nation-wide cost-benefit analysis. Agriculture, Ecosystems & Environment 66(2): 113-119.

Khouri, N.; J.M., Kalbermatten; and C.R. Bartone. 1994. Reuse of wastewater in agriculture: A guide for planners. World Bank, Washington D.C., USA: UNDP World Bank Water and Sanitation Program.

Kuo, S., Heilman, P.E. and Baker, S., Distribution and forms of copper, zinc, cadmium, ion, and manganese in soils near copper smelter. Soil Science Vol. 135, No. 2, 101-109 (1983)

Nguyen Ngoc Quynh Le Huy Ba (2000), Heavy Metals Pollution in Paddy-Soils near Ho Chi Minh City, Vietnam, Caused by Wastewater Dscharge and the Influence of Cadmium on Rice. UNESAP publication Dec.(2000).

Peralta J.R. Gardea- Torresdey, J.L. Tiemann K.J. Gomez E. Arteaga S. Rascon E. and Parsons J.G. (2000). Study of the Effects of Heavy Metals on Seed Germination and Plant Growth on Alfa Alfa Plant (Medicago sativa) Grown in Solid Media. Proceeding of the 2000 Conference on Hazardous Waste Research.

LI. H. wang. J. and hang. J. L. (1991). Removal of nutrient salts in relation with algae In ponds. Water Sci. & Tech. 24. 75-83.
Shainberg, I. and J.D. Oster, 1978. Quality of Irrigation Water, Pergamon Press. London.

WHO (1989) Healthy guidelines foe the use of wastewater in agriculture and aquaculture. Technical Report No. 778. WHO, Geneva 74p.