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Effect of Industrial Effluent of Fulad-Mobarekeh on Vegetables in Agricultural Lands

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Abstract: Monitoring industrial effluent for harmful chemicals, especially heavy metals for prevention and degradation of natural resources are required. During one-year study, the Effluent Water (EW) of Fulad-Mobarekeh, in EW irrigated area were seasonally collected for 48 h period. Also the soils, vegetable plants irrigated by well-water or EW, were sampled and analyzed for heavy metals. The EW, EC, TDS, BOD, COD, sulfate, chloride, bicarbonate, NO_3-N and Mn, Co and Cu concentration were above permissible limit, the well water EC, TDS, NO_3-N, sulfate, chloride, bicarbonate and concentration of Co and Cu were above permissible limit and soils Cu, Mn and Cd were in critical range. Soils irrigated with EW had higher OC content and available Cd, Fe, Cu, Mn, Zn and Pb concentration were higher than control. In vegetables (Taree irani and Basil plants) the Mn concentration was in the critical range and other heavy metals were in the permissible range. The concentration of Cu and Fe in Taree irani and Basil were in luxury range. The heavy metals concentration in unwashed plant samples were higher than washed samples. Results showed that industrial effluent water have limitation for application of irrigation, surface water and subsurface water. Therefore, the EW for utilization of irrigation water-resource should be monitored.

Key words: Fulad-Mobarekeh, pollution, heavy metals, permissible limit, critical limit

INTRODUCTION

The industrial Effluents Water (EW) are one of the main sources of soil and water contamination. The EW usually contains high level of hazardous materials. EW in case of entrance into the soil, surface and ground water, cause pollutions and poison food chain. Additionally, due to limited fresh water resources and increasing population; treatment and recycling of raw sewage is needed (Abbaspour, 1992). Unregulated discharge and mixing of raw sewage with the fresh water resources causes irreversible damage to environment and agricultural lands.

Heavy metals in the EW are among the main environmental pollutant. Cadmium concentration in agricultural lands in South of Tehran irrigated with wastewater were 1.5 to 2 times the control area (Torabian and Baghuri, 1996). The plant highest Cd concentration has been reported in contaminated brown rice field in Taiwan (Chen *et al*., 1994). In Taiwan more than 800 ha of land has been contaminated with industrial EW. The mean brown rice concentration of Cd, Cr, Cu, Pb and Zn were 0.07, 0.16, 2.48, 0.43 and 39.2 mg kg^{-1}, respectively (Chen, 2000). Study of the 5 regions in this country show that the soils are containing high level of Pb, Cd and other heavy metals. The Cd, Pb and Zn concentrations were ranging from 175 to 378, 252 to 3145 and 100 mg kg^{-1}, respectively (Chen, 2000).

For the past several years, China has been affected with the water pollution crisis. Three examples of wastewater pollution crisis in China are the City of Tianjin, the Chao Lakes and Xian City. City of Tianjin is the third largest industrial city in China. For many years, the construction of urban drainage, sewage and wastewater treatment (domestic and industrial) has lagged far behind the development and environmental requirements for the city (Ching, N/D). Currently, there are 400 medium and small sized cities in China,discharging 10 billion tons of wastewater every year. Up until now, wastewater pollution in China is a serious concern (Ching, N/D.)

EW application decrease the budding and growth rate of tree (Bazargan, 1988). EW Pb concentraion of selected industries of city of Yazd were less than 0.01 mg L^{-1} (Rahmani, 1997). In Bahrain Pb plants concentraion were from 9 to 240, in Canada from 100 to 300, in France from 50 to 400 and in Iran from 50 to 400 mg kg (Rahmani, 1995; Rahmani, 2001).

The objective of this field study was to investigate the level of soils, vegetables and ground water contamination by Folad-Mobarkeh EW applied for irrigation of plants.

MATERIALS AND METHODS

Fulad-Mobarekeh Industrial Iron Complex is located 70 km South West of Esfahan City and has gone through several expansion phases. It daily consumes about 109600 m^3 water. The raw EW after partial treatment is use for irrigation of agricultural land and woody plants. This research did in 2003 in agricultural lands around Fulad-Mobarekeh unit in Esfahan Province of Iran. During a one-year period, the EW was seasonally sampled for 48 h, in 8 h periods. The soil and plants in land irrigated with effluent water were sampled in 3 different districts, that are planted to Basil (*Ocymum basilicum*) and *Allium ampeloprasum* sp. *persicum* (Taree irani). In each field soils and plants were sampled in three replicates. The soil samples were analyzed for EC, SAR, texture, organic matter, cations, anions and metals including: Fe, Zn, Cu, Pb, Cd and Mn. The Effluent Water (EW) were analyzed for pH, EC, BOD, COD, TSS, TDS, NO_3-N, SAR, total hardness, cations, anions, RSC and concentration of heavy metals Fe, Zn, Cu, Pb, Cd, Mn, Ni, Cr and Co. The soil, plant and EW samples were analyzed using standard laboratory methods (APHA, 1995; Page *et al*., 1982; Robert, 1990).

RESULTS AND DISCUSSION

The results showed that the heavy metals concentration of Cd, Co, Cr, Mn and Cu in EW were higher than permissible level (EPA/ROC, 1989; Iranian EPA, 1994). The NO_3-N, BOD, TSS, COD, Cl^- and SO_4^{2-} concentrations were the limiting factors for discharge into the absorption wells; EC, SAR, TSS, TDS, NO_3-N, BOD, COD, Cl^-, SO_4^{2-} and HCO_3^- were the limiting factors for land application (Table 1 and 2).

For well-water EC, SAR, TDS, NO_3-N, Cl^-, SO_4^{2-} and HCO_3^- and heavy metal concentrations of Cd, Co, Cr, Mn and Cu were higher than permissible levels (Table 1 and 3) (EPA/ROC, 1989 and Iranian EPA, 1994). Investigation of underground water (well-water) in the EW irrigated land in the Yazd City shows that concentration of non of the Cr, Cu, Zn, Cd and Pb exceed permissible level (Rahmani, 1995) while others report contamination of soil, surface and ground water, due to discharge of EW into environment and utilization as irrigation water.

The heavy metals concentration (plant available concentration) (Table 4) in soil was higher than control. The soil concentration of Cd, Mn and Cu were higher than control and total concentration of these metals (Table 5) were in critical range (Pendias and Pendias, 1992; Allaway, 1990). Therefore,the concentration of heavy metals has increased over time and the soil has been contaminated.

Considering the results of analysis of heavy metals in soil irrigated with EW and control (the virgin land) and the high concentration level of various heavy metals in land, irrigated with EW, it is concluded that the heavy metal concentration of EW is the limiting factor and significantly ($p<0.05$) increased heavy metals concentration in soil compare with control. Also, the total content of heavy metal in soil have increased more than permissible levels therefore, has caused soil contamination. Similar results have been reported by various researchers. Many reports shows that application of untreated EW may increase the concentration of heavy metals more than permissible level (Elliott and Stevenson, 1986).

Table 1: The range of well-water (48 samples) and Effluent water (12 samples) chemical and biological properties

Parameters	Well-Water	Effluent water
pH	7.2-8	7.2-8
EC (dS m^{-1})	2.04-23.1	1.27-30.6
NO_3^--N (mg L^{-1})	0.8-118	2.8-108.2
Hardness (mg L^{-1})	350-2000	250-1400
TDS (mg L^{-1})	1280-14784	812.8-19584
TSS (mg L^{-1})	-----	30-96
BOD (mg L^{-1})	-----	23-123
COD (mg L^{-1})	-----	31-174
CO_3^{2-} (meq L^{-1})	0	0
HCO_3^- (meq L^{-1})	0-4.4	0-2.4
Cl^- (meq L^{-1})	13-1600	6.8-1000
SO_4^{2-} (meq L^{-1})	0-69	1-47
Na^+ (meq L^{-1})	14-85	1.84-72.5
Ca^{2+}+Mg^{2+} (meq L^{-1})	2-40	5-28
SAR	4.48-30.05	1.06-38.68

Table 2: The range of EW heavy metal concentration (12 samples)

Element	Cu	Zn	Fe	Mn	Pb	Cd	Ni	Cr	Co
Concentration (mg L^{-1})	0.007-0.13	0.01-0.2	0.37-1.82	<LD*-0.52	<LD-0.03	<LD	0.012-0.035	<LD 0.022	0.027-0.07

*Less than detection level

Table 3: The mean heavy metal concentration (48 samples) of well-water in study regions

Element	Ni	Cu	Zn	Pb	Cd	Cr	Co	Fe
Concentration (mg L^{-1})	0.02	0.10	0.19	0.1	<LD*	<LD	0.105	0.28

*Less than detection level

Table 4: Mean available concentration of heavy metals in soil polluted compare to non soil polluted (virgin land)

	Concentration (mg kg^{-1})					
Soil samples	Fe	Cu	Mn	Zn	Cd	Pb
Soil polluted	72.4	2.90	17.82	4.60	0.16	1.10
Non soil polluted	9.2	0.62	12.12	2.96	0.06	1.22

Table 5: Mean total concentration of heavy metals in soil samples

Heavy metals	Fe	Mn	Cu	Zn	Cd	Pb
Concentration (mg kg^{-1})	17936	551	27.7	55.8	4.4	49.4

Table 6: Mean concentration of heavy metals in washed and unwashed plant samples

		Concentration (mg kg^{-1})					
Plant	Sample location	Fe	Zn	Cu	Mn	Cd	Pb
Taree irani (shoot)	Washed	163.9	57.5	18.8	49.5	<LD*	<LD
	Unwashed	570.7	54.7	34.1	67.3	<LD	<LD
Basil (shoot)	Washed	525.2	46.3	17.5	110.4	<LD	<LD
	Unwashed	777.3	46.1	18.2	131.5	<LD	<LD

*Less than detection level

For example in Taiwan, 800 ha of agricultural land irrigated with industrial EW, the concentration of Cd, Cr, Pb, Zn, Cu in soil were 10, 16, 120, 80 and 100 mg kg^{-1}, respectively that are higher than permissible levels according to US Environmental Protection Agency standards (Frank and Martinez, 1981). Therefore, in this study the concentration of heavy metals has increased over time and the soils have been contaminated and the results are as same as other researches.

The average concentration of heavy metals in Taree irani (Table 6) shows that the concentration of Mn, Pb, Cd, Zn and Fe are less than critical range (Pendias and Pendias, 1992; Allaway, 1990) but the concentration of Mn was more than normal range and was in critical range. The comparison of the results in Basil plant with the permissible and critical levels (Pendias and Pendias, 1992; Allaway, 1990) show that the Mn concentration is in the critical range and other heavy metals are in the permissible range. The concentration of Cu and Fe in Taree irani and Basil were in luxury range.

Heavy metals concentration in unwashed plant samples were higher than washed samples(Table 6).This result shows that Fulad-Mobarekeh industrial unit have wastewater and aerosol pollution in around agricultural lands.

CONCLUSIONS

The EW has not been treated sufficiently and contain higher than permissible concentrations of many hazardous chemicals for discharge into surface water or absorption wells. The soil and water resources and plant treated with EW has been contaminated with and the concentration of heavy metals are higher than permissible levels. The increasing trend of hazardous chemical concentrations of soil, water and plant in EW treated area shows the contamination of environment by EW.

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