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Full Length Research Paper

Use of industrial and municipal effluent water in Esfahan province –Iran

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Utilization of none-prime waters in arid regions is necessary to supplement water resources. The municipal Effluent water (EW) from the Esfahan Northern Water Treatment Plant and EW of four industries of Zob-Ahan and Folad-Mobarekeh (two iron foundries), Polyacril (a petrochemical Plant) and Zohreh (a dyeing plant) were selected and their effects on soil, water resources, and plants were investigated. The result shows that for municipal EW the COD, BOD, TSS and, for industrial EW SO_4^{2-}, Cl^-, HCO_3^-, BOD, COD, N-NO_3, TDS, TSS, SAR and heavy metals concentrations of Cu, Mn, Cr, Co, Cd and Zn are the limiting factor and exceed the standard for agricultural land irrigation. In soil in land irrigated with municipal EW, the organic matter content, total nitrogen, available phosphorous and potassium and selected heavy metals were higher than well-water irrigated lands. In soils irrigated with industrial EW the concentration of Mn, Zn, Cd and Cu exceeded the normal levels, and were in critical range. The concentrations of Fe, Cu and Zn in the wheat roots irrigated with EW were higher than wheat root irrigated with well-water and the wheat grain concentration of Mn and Zn were higher than wheat grain check fields irrigated with well-water. In land irrigated with industrial EW Cu and Fe concentrations were higher than normal range. Also, Zn and Cu grain concentration increased, and Fe grain concentrations decreased compare with leaf and shoot concentration in wheat. In alfalfa, plant Cu and Zn concentrations were in critical range, and Cu, Fe, and Zn concentration exceeded the sufficient range.

Key words: Municipal, affluent water, heavy metals, permissible limit, critical limit.

INTRODUCTION

The contamination and quality of irrigation water is of the main concern especially in the regions with limited water resources. In such region not only, the water resources should wisely be utilized at the same time should be prevented from contamination. The industrial and municipal effluents waters (EW) are among the most important sources of soil and water contamination. The EW usually contains high level of hazardous material, which removal of them may not possible with routine treatments. EW in case of entrance into the soil, surface and ground water, cause pollutions and poison food chain. Additionally, due to limitation of fresh water and increasing population treatment and recycling of industrial and municipal EW is needed (Abbaspour, 1992). Unregulated discharge and mixing of raw EW with the fresh water resources causes irreversible damage to environment and agricultural lands.

Environmental contaminations by EW due to presence of heavy metals are among the main cause of environmental pollutant. In Iran, the concentrations of heavy metals in soil treated with EW have been studied (Torabian and Baghuri, 1996). For several plants, species in southern part of Tehran City the Cd concentration in EW treated area were 1.5 to 2 times higher than the none-pollutant ones. Also, in several studies the soil Cd concentration has been high. Soils and plant in south part of Tehran contain high Cd level (Torabian and Baghuri, 1996). The plant highest Cd concentration has been reported in Taiwan in brown rice contaminated soil (Chen

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et al., 1994). In Taiwan more than 800 ha of land have 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 $mgkg^{-1}$ respectively (Chen, 2000). Currently, there are 400 medium and small sized cities in China, discharging 10 billion tons of wastewater every year (N/A, 1998).Up until now, wastewater pollution in China is a serious concern.

Heavy metals have adverse effect on plant growth. The budding rate and growth of trees has been decreased by increasing Cd and Pb concentration in EW used for irrigation (Bazargan, 1988). The Pb concentration in EW of selected industries in Yazd city was less than 0.01mgL^{-1} (Rahmani, 1997). In Bahrain Pb concentration in plants were from 9 to 240, in Canada from 100 to 300, in France from 50 to 400, in England from 100 to 700 and in Iran 50 to 400 mg kg^{-1} (Rahmani, 1995; Rahmani, 2001).

In Hamedan, the application of municipal EW has increased the soil surface organic mater, available p, and k, and concentration of Cu and Zn. Application of municipal EW for table vegetable crop production increased the concentration of Cu and Zn above the critical range (Asadi and Azari, 2003).

The Zn, Mn, Cu and Fe in land irrigated with municipal EW were higher than land irrigated with well-water, but the difference were not significant (P<0.05). Corn Fe and Mn concentration, wheat grain and straw Mn and Zn concentration, tomato Fe, Zn and, Cu concentration in land irrigated with EW were higher than land irrigated with well-water (Feizi, 2001).

In Iran, the volume of non-prime water resources such as industrial and municipal EW was about $3.36*10^9$ M^3 in 1996 of which $2.5*10^9$ M^3 are from municipal sewage. In 2001, the volume of EW is predicted to be 4.5 $*10^9$ M^3, while in 2011 will rise to $7*10^9$ M^3 (Statistical handbook, 1996). Therefore, it is necessary to set a plan to study the long-term affects of EW application on the environment, food chain and, human health.

The Esfahan Province is located in a semi-arid and arid region, where the water resources are scare and water quality of should be preserved. Due to introduction of various industrial factories and high volume of municipal waste water and rapid expansion of them in the last decades, the environmental contamination of regions by heavy metals is a main concern. Therefore, the effect of industrial and municipal EW on soil and wheat and alfalfa plant will be investigated.

MATERIAL AND METHODS

The quality of municipal and industrial EW of Esfahan Northern Water Treatment plant, and industrial EW of Zob-Ahan, Folad-Mobarkeh (Iron foundries), Polyacril (petrochemical plant) and Zohreh (dyeing plant) and its impact on soil, plants and water resources (well-water) were studied for two years. The EWs and well-water from an area irrigated with EW were seasonally sampled every 6 h during 24 h periods.

During a two-year study, in an area where was using municipal EW, four farms were selected (3 irrigated with EW and one irrigated with Well-water). In area irrigated with industrial EW two zone were selected, one irrigated with industrial EW from Zob-Ahan and one irrigated With EW from Folad-Mobrakeh.

In each zone, 3 farms of approximately 0.5 ha were selected. In each farm, composite soil sample from three fields from 0 - 30 cm were collected in three replicates. In fields irrigated with industrial EW the soil, plant, and control filed were sampled. In fields irrigated with municipal EW, wheat root, shoot, and grains and in fields irrigated with industrial EW, Wheat grain and shoot, and alfalfa were sampled.

The EW and well-water were analyzed for pH, EC, TDS, TSS, $N\text{-}NO_3$, cations (Na^+, Ca^{2+} and Mg^{2+}), anions (CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-), BOD, COD, and the total concentration of heavy metals including Cu, Zn, Mn, Ni, Co, Cd, Fe, Pb and Cr (APHA, 1995). The soil samples were analyzed for pH, EC, texture, organic matter, cations, anions and concentration of heavy metals including Cu, Cd, Zn, Fe, Mn and Pb (Page et al., 1982). The plants samples were analyzed for percent dry matter content and the same heavy metals as soil samples (Robert, 1990). The results were compared with permissible concentration levels.

RESULT AND DISCUSSIONS

Effect of municipal EW on soil, water and plant

Table 1 shows the mean and range of chemical properties of the northern Esfahan municipal EW and, local well-water. The results show that the concentration of heavy metals in well-water and EW were very low and did not exceed the permissible levels (IEPA, 1994; EPA / ROC, 1989). The EC of well-water and EW for irrig-ation purposes were very limiting and not limiting, respectively. The BOD, COD, TSS, of EW for irrigation application was limiting (IEPA, 1994; EPA/ROC, 1989).

Soil samples irrigated with well-water, and few of the soil samples irrigated with EW were saline (EC>4 dS m^{-1}), due to saline well-water and long-term utilization of EW. In all soil samples collected from the land irrigated with EW (Table 2) the amount of organic matter, total N, available P and K and heavy metals were higher than soil irrigated with well water, the difference were significant (P<0.05). Concentration of Fe, Zn, Cu, and, Cd in wheat roots irrigated with EW were higher than wheat roots irrigated with well water. The Mn and Zn concentration of grain and shoot irrigated with EW were significantly higher than well-water (P<0.05). The effect of irrigation water sources on the Pb concentration of root was not signifycant (P<0.05).

Even though the heavy metals concentration in EW did not exceed the permissible levels (Alloway, 1990; Pendias and Pendias, 1992), the concentration of heavy metal in soil and plants irrigated with EW had increased in comparison to the control. The result shows the long-term heavy metal accumulation in soil. Although the result of

Table 1. The mean and range of chemical properties and heavy metal concentration of well-water and municipal effluent water.

Parameter	Well-Water		Effluent	
	Range	Mean	Range	Mean
pH	6.6-6.7	6.6	7.2-7.55	7.4
EC (dS m^{-1})	6.27-11	8.36	-----	1.49
BOD (mg l^{-1})	-----	----	145-246	178.7
COD (mg l^{-1})	-----	----	192-352	248
TSS (mg l^{-1})	-----	----	70-124	88.7
Fe (mg l^{-1})	<LOD*	<LOD	-----	0.12
Cu (mg l^{-1})	<LOD	<LOD	-----	<LOD
Zn (mg l^{-1})	<LOD	<LOD	-----	<LOD
Mn (mg l^{-1})	<LOD	<LOD	-----	<LOD
Cd (mg l^{-1})	<LOD	<LOD	-----	0.05
Pb (mg l^{-1})	<LOD	<LOD	-----	<LOD

* Less than detection level.

Table *2.* Heavy metal concentration and chemical properties of soil irrigated with well-water and municipal effluent water.

Parameter	Well-Water		Effluent	
	Range	Mean	Range	Mean
pH	7-7.5	7.19	7.1-7.3	7.2
EC (dS m^{-1})	2.01-6.17	4.44	7.85-11.84	9.85
OC (%)	1.2-1.8	1.6	0.97-1.08	1.03
N (%)	0.12-0.18	0.16	0.097-0.108	0.103
Available P (mg kg^{-1})	43.4-82.3	67.3	5.3-12	8.7
Available K (mg kg^{-1})	393.7-961	752	220-267	243.5
Mn (mg kg^{-1})	15.56-41.50	28.99	15.96-16.41	16.9
Cu (mg kg^{-1})	1.40-2.85	2.17	1.23-1.47	1.35
Cd (mg kg^{-1})	<LOD	<LOD	<LOD	<LOD
Zn (mg kg^{-1})	1.09-2.49	1.98	0.63-0.79	0.71
Fe (mg kg^{-1})	7.27-20.67	11.9	5.49-5.71	5.6
Pb (mg kg^{-1})	2.97-3.75	3.24	2.02-2.07	2.05

EW application in agricultural land were shown that EW heavy metal content are not harmful (Ellioti and Stevenson, 1986) , but some research results were indicated that EW may increase soil heavy metal concentration more than permissible levels(Ellioti and Stevenson, 1986).

Biological and chemical properties of industrial EW and their effects of on soil, water and plant

The range of chemicals properties and concentration of heavy metals in industrial EW and the well-water located in the irrigated are given in Table 3. The comparison between the results obtained and the permissible level(IEPA, 1994; EPA/ROC, 1989) shows that BOD, COD, TSS, TDS, N-NO_3, Cl^-, SO_4^{2-} and heavy metal concentration of Zn, are limited for discharge into surface water and, disposal into absorption wells and heavy metal concentration of Cd, Cr, Co, Cu, Mn, and Zn for utilization as the irrigation water.

The limiting chemicals properties in well-water for discharge into surface water are N-NO_3, Cl^-, SO_4^{2-}, and heavy metal concentration of Fe (in one well-water). For irrigation of agricultural land the heavy metal concentration of Fe, Co, Cu, exceeded the permissible levels (IEPA, 1994; EPA/ROC, 1989).

According to Table 4, the available concentration of heavy metal in soil samples (extracted by DTPA) (Page et al., 1982) are higher than in control. In addition, the concentration of Cd, Mn, Cu, and Zn heavy metals were

Table 3. The range of chemical properties of industrial effluent and well-water.

Parameter	Range \Effluent-Water	Well- Water
pH	6.5-8	6.8-7.6
EC (dS m^{-1})	0.57-30.6	2.04-25.0
$N-NO_3$	0.7-165.8	0.80-118
Hardness	200-2800	350-3400
TDS(mg/l)	364.8-19584	1280-14784
TSS (mg /l)	28-138	---
BOD(mg /l)	6-123	---
COD(mg /l)	31-517.2	---
Co (mg /l)	0.039-0.095	0.107-0.200
Cr (mg /l)	0.013-0.129	<LOD-0.252
Cd (mg /l)	<LOD-0.068	<LOD
Pb (mg /l)	<LOD-0.068	0.096-0.130
Zn (mg /l)	0.17-2.143	0.192-0.248
Cu (mg /l)	0.06-0.129	0.099-0.125
Ni(mg /l)	0.014-0.055	0.018-0.175
HCO_3^- (meq/l)	0-7.6	0-4.4
Cl^-(meq/l)	3.2-2000	13-1600
SO_4^{2-} (meq/l)	0-47	0-69
Na^+(meq/l)	1.84-83	14-85
Ca^{2+}+Mg^{2+} (meq/l)	4-56	2-68
SAR	1.06-38.68	4.48-30.05

Table 4. The range of available and total concentration of heavy metals in soil treated with industrial effluent water and check fields (well-water).

Element	Available Concentration (mg kg^{-1})		Total Concentration (mg kg^{-1})
	Effluent Water	Check	Effluent Water
Pb	1.6-12.2	1.1-1.4	51.3-57.7
Cd	<LOD-1.4	<LOD	10. 3-12.8
Zn	13.9-45.9	1.8-2.9	60.3-74.4
Mn	18.0-20.6	11.7-12.3	509.0-551.3
Cu	3.6-8.3	0.66-1.1	28.2-38.4
Fe	45.0-65.1	4.8-9.0	NM*

Table 5. The range of concentration of heavy metals in Wheat and Alfalfa.

Element	(mg kg-1 dry weight)		
	Wheat(shoot)	Wheat(grain)	Alfalfa(shoot)
Pb	<LOD	<LOD	<LOD
Cd	<LOD	<LOD	<LOD
Cu	6.1-7.1	4.6-10.8	26.7-52.5
Zn	6.1-8.6	15.9-50	51.7-66.7
Fe	145.5-158.1	90.5-93.6	291.7-297.5
Mn	NM*	NM*	18.3-39.2

* not measured

exceeded normal levels (Alloway, 1990; Pendias and Pendias, 1992), which were in the critical range. Similar results have been reported by numerous researches (Chen, 2000; Elliott and Stevenson, 1986; Webber and

Singh, 1994). The results imply that the heavy metals were accumulated in soil due to the long term irrigation with EW. Comparison of the result in Table 5 with the permissible level, shows that the concentration of heavy metals (with exception of Zn and Fe) do not exceed the permissible level (Alloway, 1990; Pendias and Pendias, 1992) in wheat shoot and grain. The Cu concentration in shoot is higher than sufficient range, while econcentration in wheat grain is higher than sufficient rang. The concentrations of Cu and Zn in alfalfa plant are in critical range and the concentration of Zn, Fe and, Cu are higher than sufficient range. The wheat plant has the tendency to accumulate more Zn and Cu and less Fe in the root in comparison to the shoot. The concentration of Cd and, Pb in wheat and alfalfa were very low.

Plants uptake of heavy metals has increased by long-term irrigation with industrial EW. Nowadays, the quality of EW plays an important role in contamination of soil, plant, and water resources. The long-term application of EW may lead to serious contamination and accumulation of heavy metals exceeding the permissible ranges.

Conclusion

Utilization of the none-prime water resources, especially industrial and municipal effluent water in the arid region for agricultural land is needed. However due to chemical and biological limitation of EW, regarding the heavy metal concentration and its introduction into the human food chain, it is recommended to; fully treat before discharge into the environment to be used for plant with low tendency to accumulate heavy metals and monitoring of water resources taking necessary precautions in order to prevent the contamination of underground water resources.

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