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EVALUATION OF POSSIBLE OPTIONS FOR REUSE OF ARDEBIL WASTEWATER TREATMENT PLANT EFFLUENT

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ABSTRACT

Recent advances in wastewater treatment have resulted in production of well-treated effluents which are suitable for use in more different sectors. In fact, these reclaimed wastewaters would be regarded as new water resources in many regions. In this research, the area studied was the city of Ardebil in northwest of Iran. At present, the effluent of Ardebil wastewater treatment plant is discharged into Qaresoo River. In this study, different aspects of Ardebil wastewater reuse have been investigated. Sampling of the effluent was performed in winter 2006 and summer 2007; and parameters indicating the suitability of wastewater discharge and/or reuse were considered in accordance to the recommendations of Iran Department of Environment. All the analyses were accomplished according to the latest edition of standard methods. Results clearly showed that apart from the problem of total and fecal coliforms which were above the standard values (1000 MPN and 400 MPN per 100 mL) the reuse of the treated effluent in agricultural irrigation could be carried out without restriction. But, regarding the discharge of this effluent into surface waters and injection wells, it would be necessary to upgrade treatment processes for further reduction of a few parameters such as nitrate, ammonium and phosphate.

Key words: Wastewater treatment, water reuse, agricultural irrigation, Ardebil

INTRODUCTION

Inadequate water supply and water quality deterioration represent serious concerns for municipalities, industries, agriculture and the environment in many parts of the world. Factors contributing to these problems include continued population growth in urban areas, contamination of surface water and groundwater, heterogeneous distribution of water resources, and frequent droughts caused by extreme global weather patterns (UNESCO, 2003). Hence, a severe water shortage is predicted for about 2.7 billions people in the year 2025 (HRH, 2002). For more than a quarter century, a recurring thesis in environmental and water resources engineering has been that improved wastewater treatment provides a treated effluent of such quality that it may be put to beneficial uses. This conviction in responsible engineering, coupled with increasing water shortages and environmental pollution, provides a realistic framework for considering reclaimed wastewater as a water resource rather than a liability (Asano *et al*., 2004).

Reclaimed wastewater from municipalities and industries has been used as an additional source of water supply in many parts of the world, especially in areas where water resources are scarce and population and economic growth is rapid. Reclaimed wastewater can be used for many purposes including agricultural irrigation, groundwater recharge, car washing, toilet flushing, urban lawn watering and recreational amenities and road cleaning although, agricultural irrigation has been by far the major use in many areas where wastewater is reclaimed. This is mainly because of the large water use in irrigation, relatively low quality requirements and relatively low cost of

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infrastructure for the irrigation water supply. Concerns on health impact of using reclaimed wastewater, especially for agricultural irrigation and groundwater recharge have also drawn an increasing attention in the last decade (Barbagello *et al.*, 2001; Tsagarakis and Georgantzis, 2003) therefore the planning and management of agricultural reuse projects need to consider institutional and legal, socio-economic, financial, environmental and technical aspects (Lazarova *et al.*, 2000). Most of the aspects have still to be studied in more detail since they require the development and reuse of appropriate strategies and qualified bodies for local management of treatment projects. One important key issue is often the lack of the institutional setting and guidelines or measures to be able to implement a planned reuse project. The need for adaptation of the guidelines to the specific area of concern is high and still a challenge to all involved disciplines. The adaptation to the local conditions should increase the benefits and decrease the health risks.

Furthermore, this will result in a higher public acceptance which is crucial for implementation of reuse projects. Agriculture can be considered as a land treatment system for wastewater and soil as a bioreactor in which contaminations are attenuated. Nevertheless, quality requirements of the treated wastewater used for irrigation purposes have to be met (Juanico, 1993 and Tchobanogloys *et al.*, 1999). Sewage farms namely farms which use wastewater for irrigation of crops are numerous in many countries of Europe and America and it seems that this trend is ever increasing (Mara, 1989).

Groundwater recharge is another option for wastewater reuse. Natural replenishment of underground water occurs very slowly; excessive exploitation and mining of groundwater at greater than the rate of replenishment causes declining water tables in the long term and lead to eventual exhaustion of groundwater resource. Artificial recharge of groundwater basins is becoming increasingly important in water management and particularly where conjunctive use of surface water and groundwater resources is considered in the context of integrated water resources management (Asano *et al.*, 2004).

The main purposes of artificial recharge of groundwater have been: (a) to reduce, stop, or even reverse declines of groundwater levels, (b) to protect underground freshwater in coastal aquifers against saltwater intrusion and (c) to store surface water, including flood or other surplus water, and reclaimed municipal wastewater for future uses. Groundwater recharge is also incidentally achieved in irrigation and land treatment and disposal of municipal and industrial wastewater via percolation and infiltration(Asano *et al.*, 2004).

The city of Ardebil is located in northwest of Iran (Fig. 1). The rainfall rate of this region is estimated as 291 mL in long term according to local meteorological data. The region is considered as an agricultural zone and water needed for various activities is obtained from groundwater aquifers.

The groundwater depth is between 42 m in the slope of mountains and 1 m in plain areas. The existing information shows that about 8/37 m decline has been occurred in water depth during the past 30 years (Ardebil Regional Water Dept., 2005) thus water supply for irrigation and industrial activities has become a series concern for managers of Ardebil province. The wastewater treatment plant (WWTP) of Ardebil is located at 10 Km distance in northeast of the city. It is designed in 8 similar phases, each comprised of 2 parallel modules. The first and second modules related to the first phase are in operation recently. The various operational units of the wastewater treatment plant are pumping station, bar screening, two complete mix aerated lagoons, sedimentation pound and chlorination chamber, but the disinfection chamber is not complete (Mahab Qods Eng. Co., 2006).

Although, wastewater reuse for this region should be considered important for meeting the ever-increasing demands of water, but this strategy should be accomplished with correct management and by minute control of effluent quality to prevent further contamination of water resources and soil in the region. At present, the effluent of Ardebil WWTP is discharged into the Qarasoo river and is indirectly used by farmers of downstream regions. In this study, different aspects of reuse potentials for Ardebil WWTP effluent have been investigated during autumn 2006 to winter 2008.

Fig. 1: Schematic View of the Wastewater Treatment Plant of the City of Ardebil

MATERIALS AND METHODS

For specifying the suitability of Ardebil WWTP effluent for reuse in different purposes (irrigation, discharge to injection wells or surface waters), the standards recommended by Iran Department of Environment (DOE) have been selected as the leading criteria(Iran Dept. of Environment, 1992); sampling of the effluent had been done monthly in two seasons (winter of 2006 and summer of 2007) in order to specify the influence of temperature fluctuations. The composite wastewater samples were gathered four times a day (with equal intervals of 6 h) and were sent to the laboratory (in the School of Public Health, Tehran University of Medical Sciences) after performing required preservation techniques. All the analyses were accomplished according to the procedures described in Standard Methods (APHA, 2005).

For determining the suitability of the effluent in agricultural irrigation, special parameters such as salinity, permeability and toxicity should be considered. In this respect, total dissolved solids (TDS) and electrical conductivity (EC) were measured for determination of salinity, concentrations of calcium, magnesium and sodium were measured for determination of permeability, and concentrations of boron, chloride and sodium were measured for specifying the effluent toxicity. It should be mentioned that the other important parameters indicating the suitability of a water sample for use in irrigation are Sodium absorption ratio (SAR) and exchangeable sodium (Na%). SAR and Na% have also been determined by using the following equations:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad (1)$$

$$Na\% = \frac{Na^{+} \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad (2)$$

Concentrations of cathions in both equations are expressed as milli equivalent per liter.

Microbiological parameter and heavy metals concentrations have been also measured for determining the health risks. Moreover, sampling and analyses of soils in the downstream of the WWTP in agriculture areas were accomplished in this study, in order to select the appropriate crops.

RESULTS

Table 1 presents the comparison of effluent qualitative characteristics with national wastewater reuse standards. Comparison of the important parameters in Ardebil WWTP effluent with regulated values for irrigation water is also shown in Table 2.

DISCUSSION

As can be seen in Table 1, the average concentrations of TDS and SAR in Ardebil effluent were 1144 mg/L and 6.28 in the period of this study. Concerning these parameters, it could be concluded that there would be no problem for use of this effluent in irrigation since the amounts are all in the acceptable ranges of WHO standards. It should be added that Iran Department of Environment had not published a perfect standard in this respect. Results obtained by analysis of soil samples belong to the farms in downstream and/or around the Ardebil WWTP indicate that irrigation of crops with limited drainage would not be appropriate and the crops permissible for this irrigation should not be sensitive to salinity.

Certainly, the effluent would become more suitable for use in irrigation, by adequate drainage and washing operations thus vegetables such as wheat and barely could be irrigated with respect to agricultural patterns of this region. By comparing the EC of the effluent with the WHO guideline values, it could be concluded that use of this effluent in irrigation is accepted if low to moderate restriction is considered. Besides, no serious problem about increase of salinity would be experienced by correct management and appropriate soil drainage and when it would be possible to prevent further increase of effluent TDS.

Another aspect for reuse of wastewater is the concentration of nutrients. According to Table 1, concentrations of phosphorous, nitrate, nitrite and ammonia in Ardebil WWTP effluent were in the ranges of 8.3-14.5, 10.3-26.7, 1.36-3.09 and 9.12-17 mg/L, respectively. Although their presence in water has no detrimental effect on plants and indeed they are essential for growth of many plants, discharge of agricultural runoff containing high concentrations of nutrients to water resources may cause eutrification; thus their concentrations should be controlled although in this respect no regulation had been promulgated by DOE. Besides, nutrients conc. control is especially important for the region because the role of Ardebil plain in recharging local aquifers is very high compared to other fields around the Arass river located in the north. Therefore, agricultural activities by this effluent may raise the risk of groundwater pollution to nitrate.

As can be seen in Table 2, the amount of SAR calculated for Ardebil effluent is less than 10 indicating the suitability of this effluent for irrigation uses without any restriction. But, with respect to chloride with average concentration of 221 mg/L (standard deviation of 11.4), it should be admitted that not all crops are allowed for irrigation since it is probable that chloride produces same toxicities in sensitive and semi-resistant plants. However, comparing the concentration of chloride to national standards, we recognize that there would be no important restriction in reuse of Ardebil effluent

Table 1: Comparison of effluent characteristics of Ardebil Wastewater Treatment Plant with standards published by Iran Department of Environment for discharge and reuse of wastewaters

Parameter	Unit	Average amount in WWTP effluent	SD	Approved Standards		
				Discharge into injection wells	Discharge to surface waters	Agricultural reuse
COD	mg/L	97.87	23.21	60	60	200
BOD_5	mg/L	57.25	14.19	30	30	100
pH	-	7.61	0.4	5-9	6.5-8.5	6-8.5
Turbitidy	NTU	21.31	10.03	–	50	50
Chloride	mg/L	220.90	11.41	600	600	600
Oil and grease	mg/L	48.81	14.49	10	10	10
Detergent	mg/L	0.51	0.18	0.5	0.5	0.5
DO	mg/L	5.14	-	-	2	2
Magnesium	mg/L	34.75	8.02	100	100	100
Calcium	mg/L	95.46	25.91	–	75	-
TSS	mg/L	29.16	7.58	–	40	100
TDS	mg/L	1144	79.94	Note 2	Note 1	-
Total coliforms	MPN	7.3×10^5	6.5×10^5	1000	1000	1000
Fecal coliforms	MPN	2.3×10^4	1.7×10^4	400	400	400
Parasitic eggs	No./L	<1	-	–	–	-
Ammonia	mg/L	13.57	3.39	1	2.5	-
Nitrate	mg/L	19.3	5.75	10	50	-
Nitrite	mg/L	2.31	0.65	10	10	-
Phosphate(as P)	mg/L	11.59	2.29	6	6	-
Boron	mg/L	0.097	0.13	1	2	1
Iron	mg/L	5.25	5.08	3	3	3
Aluminum	mg/L	0	0	5	5	5
Manganese	mg/L	1.3	0.76	1	1	1
Lead	mg/L	0.67	0.07	1	1	1
Zinc	mg/L	0.76	0.23	2	2	2
Copper	mg/L	0.08	0.05	1	1	0.2
Cadmium	mg/L	0.03	0.01	0.1	0.1	0.05

Note 1: Higher concentration is permissible in effluent provided that concentrations of chloride, sulfate and TDS would not be increased in receiving water to more than 10 percent up to 200 m after discharge

Note 2: The number of parasitic eggs in treated effluent should not be more than 1 per liter, if it is used in irrigation of crops which are eaten raw

Table 2: Comparison of effluent characteristics of Ardebil Wastewater Treatment Plant with approved criteria for irrigation water (FAO)

Water Quality	B^-(mg/L)	Cl^-(mg/L)	Na (%)	EC (ms/cm)	SAR_W
Excellent	0.5	<70	<20	<250	<10
Good	0.5-1	70-140	20-40	250-750	10-18
Permissible	1-2	140-280	40-60	750-2000	18-26
Doubtful	2-4	>280	60-80	2000-3000	>26
Unsuitable	>4	–	>80	>3000	–
Ardebil WWTP Effluent Characteristics	0-0.35	205-232	31.5-38.09	1807-2005	4.85-7.87

for any of the permitted options. Other important criteria for water use in irrigation are Na% and boron concentration. In Ardebil effluent, the average value of Na% was 31.5-38.09. which is higher than 20 (the standard value), hence it may not be considered as an excellent effluent for irrigation of all crops. Nevertheless, there would be no problem or restriction in irrigation of dominant plants in Ardebil region namely wheat and barely which are well resistant to this level of Na%.

Concerning the element of boron which its concentration was insignificant during the period of this study, the Ardebil effluent can be considered as an excellent source of water.

Effluent use in agricultural irrigation and selection of vegetables should be based on principles by which edible crops irrigated could not be polluted to pathogenic microorganisms remained in the effluent. With respect to the data obtained in this study about the quality of Ardebil WWTP effluent and considering the existing treatment stages of Ardebil WWTP, it could be concluded that irrigation of crops which are consumed without cooking may not be recommended in the region. Besides, application of this effluent for irrigation of crops such as potato and beetroot which are produced within the soil is also unprofitable because of direct contact of these crops to polluted soils. These important considerations should not be forgotten as long as the chlorination unit of this treatment plant is not active. Moreover, it is essential to stop the practice of irrigation at least two weeks before the time of collecting the crops. Of course, irrigation by the effluent for crops that are consumed after processing, may be continued by this effluent. Examples of these permissible crops are wheat, barley and cereals. Irrigation of fruit gardens with this wastewater is also acceptable but it is better that this practice would not be continued for those fruits which are consumed freshly, because of possible contamination by soil. On the other hand, those trees such as walnut and almond which their fruits are consumed when dried are permissible for this irrigation as well as the trees like pine, cypress and elm which their woods are valuable. Besides, irrigation of industrial crops such as cotton by this effluent can be continued without any restriction. In fact, the best practice is allocation of this effluent in irrigation of non-edible crops and trees having valuable wood because possible accumulation of some pollutants like heavy metals remained in wastewater effluents may subject consumers of edible products to diseases, in long-term consumption. It should be also noted that irrigation of landscape and public gardens is not acceptable.

It should not be neglected that agricultural activities and demand of all plants to water are much less in cold seasons, thus there would be need to have appropriate provisions for correct storage and/or disposed of effluent in periods of interrupting irrigation.

At present, indirect reuse of Ardebil effluent in which treated treatment wastewater of Ardebil is discharged to Qaresoo river for subsequent agricultural abstractions is accomplished. This would not be an approved practice if wastewater is not well treated, because the farmers and all the residents in the villages may be faced to health risks. Thus, it is essential to have a correct program for upgrading the Ardebil WWTP as soon as possible, and at the first step it is essential to disinfect the effluent for meeting the national standards for total and fecal coliforms which are 1000 and 400 in 100 mL. In addition to microbiological parameters the quality of Ardebil effluent is not suitable for discharge from chemical point of view (see Table 1, parameters of N, P, detergents and oil and grease). Also, results of this study clearly showed that this effluent should not be used in artificial recharge because this action may deteriorate the quality of local groundwater.

Wastewater reuse projects have been of special interest in Iran because of their potential in producing significant water savings in this water stressed country. In the year 2000, a research for determining the potential of wastewater reuse in Kish Island had been accomplished by Ghaneian. Results indicated that the effluent of Kish WWTP was not suitable for agricultural irrigation from the view point of indicator microorganisms (fecal and total coliforms). Besides, it was revealed that the effluent was somehow saline thus, its use was not considered to be appropriate in irrigation of sensitive crops. In another research conducted by SalehiArjmand *et al.*, (2004), the emphasis was placed on determining the concentrations of chemical constituents present in Arak WWTP effluent, and in this way the amounts of many heavy metals were measured. They finally reported that no chemical contamination was present, thus concluded that many crops could be irrigated by this effluent. However, their recommendation was specifying the effluent for irrigation of non-edible crops.

Study of the wastewater reuse opportunities for the city of Yazd was the subject of research conducted by Amjad *et al.*, in 2006. The WWTP of Yazd is based on a series of stabilization ponds and use of the final effluent in agricultural irrigation was considered to be a safe action.

Other options for using secondary effluents are in urban non-potable applications and in local industries, which should be specially considered for situations where farms are far from cities. With this respect, many researches have been done in several countries and in Iran, study of these options were the subject of a few projects as well (Safari, 2001 and Mosaferi, 1998). These studies have shown that for reuse of effluents in sections other than irrigation there would be need to have wastewater treatment stages more than the traditional secondary treatment. However, to ensure the best option for reuse of wastewater in a special region, preparing an appropriate report about environmental impact assessment would be necessary (Nabizadeh and Jafarzaded , 1999).

Finally, we conclude that upgrading the existing wastewater treatment plant of Ardebil along with regular monitoring of the final effluent would be the best solution for prevention of the mentioned problems in this region and a needful practice in developing use of the effluent for various purposes.

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REFERENCES

APHA, AWWA, WPCE., (2005). Standard methods for the examination of water and wastewater. 21th Ed.

Ardebil Regenal Water Department, (2005). Report on studies about groundwater resources of Ardebil Plain. Periodical Publication. (1071).

Asano, T., Joseph, A., Cotruvob, C., (2004). Groundwater recharge with reclaimed municipal wastewater, health and regulatory considerations. Water Research., **38**: 1941-1951.

Amjad, M., Salimi Saboor, S., and Maghsoodloo, B., (2006). Study the opportunities of reusing municipal wastewater of the city of Yazd. 9th National Congress on Environmental Health. Isfahan.

Ayers, R. S., Westcot, D. W., (1985). Water quality for agriculture. FAO.

Barbagello, S., Cirelli, G. L. and Indelicato, S., (2001). Wastewater reuse in Italy. J. Water Sci. Technol., **43**: 43-50.

Ghaneian, M. T., (2000). Study the characteristics of municipal wastewater in Kish Island and options for reuse. MS Thesis in environmental health eng. School of Public Health. Tehran University of Medical Sciences.

HRH the prince of orange (2002). No water no future: A water focus for Johannesburg.

http://www.nowaternofuture.org/pdf/NW_NF_August2002.pdf.

Iran Department of Environment., (2002). Iranian effluent discharge standards.

Juanico, M., (1993). Alternative schemes for municipal sewage treatment and disposal in industrialized countries: Israel as a case study. J. Ecological Engineering., **2**: 101-118.

Lazarova, V., Levne, B., Sack, J., Cirele, G., Jeferey, P., Muntau, H., Brissaud, F. and Salgot, M., (2000). Role of water reuse in enhancement of integrated water management in Europe and Mediterranean countries. 3rd Integrated Symposium on Wastewater Reclamation, Recycling and Reuse: France 3-7. July 2000.

Mahab Qods Eng. Co., (2007). Report on sewerage network system and WWTP of Ardebil.

Mara D.,(1989). Guidelines for correct use of wastewater and excreta in agriculture and aquaculture. Translated to Farsi by Research Deputy of Ministry of Health in Iran (in 1997).

Mosaferi, M., (1998). Study the possible options for reuse of the effluents of food and pharmacological industries of Tehran. MS thesis in environmental health Eng. School of Public Health. TUMS.

Nabizadeh, R. and Jafarzadeh, N., (1999). Assessment of environmental impacts caused by wastewater reuse projects. Water & Environment., (34) 40-55.

Pescod MB., (1992). Wastewater treatment and use in agriculture. FAO irrigation and drainage paper., 47-125. Food and Agriculture Organization. Rome.

Safari, Gh. H., (2001). Study the effectiveness of floating media filtering in preparing effluent for urban non potable applications. MS thesis in environmental health Eng. School of Public health. TUMS.

Salehi Arjmand, H., Mehdian, MH., Kargari, A. and Mehdia, M., (2006). Study the possibility of reusing Arak WWTP effluent in agriculture. Water and Environment., (65) 41-46.

Tchobanoglous, G. and Angelakis, A., (1996). Technologies for wastewater treatment appropriate for reuse of wastewater and global water management Water Science Technol., **33**:15-24.

Tsagarakis, k. p. and Georgantzis, N., (2003). The role of information on farmers willingness to use recycled water for irrigation. J. Water Supply., **3**: 105-113.

UNESCO., (2003). Water for people- water for life, The United Nations World. Water Development Report. UNESCO Publishing/Berghahn Books: also available at:http://www.un.org/esa/sustdev/sdissues/water/www.english-129556 e.pdf.