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CASE STUDY

Quality assessment of treated wastewater to be reused in agriculture

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ABSTRACT: In this study, the quality of a treated wastewater for agricultural and irrigation purposes was investigated. 39 quality parameters were investigated at the entrance of an effluent channel to the destination plain in monthly time intervals during a year. The aim of this study was drawing an analogy between analyses results and the latest standards in the world (nationwide and internationally), the agricultural and irrigation usage indexes and the Wilcox diagram. The results showed that some parameters such as turbidity, total suspended solids, electrical conductivity, sodium, detergents, total coliform and focal coliform, ammonium, residual sodium carbonate, the Kelly's Ratio and the Wilcox diagram were exceeding the permissible limit and are not suitable for agriculture and irrigation. It was found that the aquifers in the study area were polluted by natural salinity and geogenic source. As a result, application of the treated wastewater from Qom for agriculture and irrigation purposes needs to be revised and monitored. An action plan is also needed to manage a huge source of water and to avoid further environmental and health risks.

KEYWORDS: *Effluent quality; Irrigation; Reuse; Salinity index; Water resource management.*

INTRODUCTION

Clean water is a daily and essential need for everyone and for each community. Hence, in the last decade, providing clean water for drinking and for industry and agriculture has become the main concern of governments. The concerns (shortage and lack of water) are more in arid and semiarid areas because of the absence of surface water, population growth, increase in water and food demands and urbanization problems. All these phenomena have attracted more attentions to groundwater resources, turning them into an invaluable commodity (Barker *et al.,* 1998). Increase in water demand has led to even more groundwater exploitation and deficiency in water resources and has caused high volume of wastewater. This has made the water and agriculture management organizations further determined to artificially recharge aquifer and to irrigate farms by the treated wastewater (TWW). Considering the health and food-social security effects, the impact on plants (growth and rate of production), the irrigation system and physical and chemical features of soils (Qader and Ghazal, 2008), reuse of these waters for irrigation and agriculture needs to meet some quantity and quality standards. Thus, due to water scarcity for agricultural use, particularly in arid and semiarid areas and in areas with water shortage, it is essential to monitor the quality and quantity of TWW according to proper standards by competent authorities. Some important water quality parameters for irrigation of the public green spaces and for agricultural use include temperature which is effective on plant growth and germination (Danesh *et al.,* 2011); total dissolved solid which is effective on permeability and hydraulic conductivity (Huck *et al.,* 2000) and on irrigation system like clogged nozzles; dissolved oxygen content which is effective on activity and environmental condition

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of organism activity (Metcalf *et al.,* 2007; Metcalf et al., 2014); sodium content which can impose damage to the root and stem tissue and destroy soil structure and also can reduce permeability and crop production (Ayers and Westcot, 1985; Sridharan and Senthil Nathan, 2017; Tak *et al.,* 2012); sulfur content which is effective on the rate of growth and on crop production; chloride ion which can cause poisoning of the plant and crops (Ayers and Westcot, 1985); coliform content which can cause prevalent disease of bacterial, viral, radionuclide and parasitic sources (Danesh *et al.,* 2011); and the number of nematode eggs and some elements such as lead and chrome which can cause Proteinuria as well as boron which can induce poisoning in plant. Usage of the TWW has some advantage and disadvantages. The advantage of irrigation by TWW are listed below.

In arid and semiarid areas and even in humid areas where suitable water for drinking and agriculture is not available permanently and seasonally, wastewater use can help management of the water resource. Some benefits are: management and preservation of drinking water which seems definitive, while triggered by long- term droughts caused by climate change and rainfall drop; availability of high and distinct volume of wastewater annually and based on the number of population; wastewater which has a high valuable amount of nutrient and organic matter can be used to reduce the amount of chemical fertilizer and rise the crop production; reduction and elimination of the eutrophication danger in the water surface body (particularly in lakes and dams); improvement of the soil structure/texture, rising the plant growth and crop production by irrigation management (Asano and Levine, 1996; Fatta and Kythreotou,2005; Alkhamisi and Ahmed, 2014). In addition to the wastewater benefits, there are some other concerns about collection, storage, purification and associated environmental problems. Some problems and concerns about the wastewater usage are: wastewater ingress into the surface waters/streams and occurrence of eutrophication which are effective on irrigation systems instruments (like the nozzles' clogging) (Danesh *et al.,* 2011); increase in the ingress of nitrate into groundwater (Bond, 1998), increase in salinization and sodic level of soil ; contingency of incurring public health problem by improper treatment of wastewater (Bond, 1998); contingency of the contamination of surface and groundwater resources (salts, sodium, nitrate, phosphate and etc.) (Bond, 1998); wastewater accumulation up to the poisoning levels in soil and plants and its consequence leachate into the ground water (Bond, 1998); and increase in content and concentration of heavy metals (particularly lead, zinc and cadmium) in soil that can decrease their stability capacity by the soil and their movements from soil into the plants, animals and humans. Today, the World Health Organization (WHO) has plans to reuse water and recently has published guidelines in this regard (WHO, 2017). However, in some developing countries TWW for agricultural use is still far away from related standards and guidelines (Moghadam *et al*., 2015). In the current study, according to the high volume of TWW that are available for agriculture and green space irrigation purposes, Standards of Iranian Department of Environment, environmental criteria for treated wastewater and return flow reuse (Issue No: 535, 2010), World Health Organization guideline (Mara and Carincross,1989; WHO, 1981; WHO, 1989; WHO, 2006), US Environmental Protection Agency guideline (Murray, 1977; USEPA, 2012) and Food and Agriculture Organization (FAO) guideline (Doneen and Westcot, 1984; Ayers and Westcot, 1985; FAO, 1989, Pescod, 1992) are used to study the quality and quantity conditions of TWW from Qom for agriculture and green space irrigation objectives. This study has been carried out in Sharif Abad plain of Qom city in Iran during 2013-2014.

Wastewater and Sharif Abad plain condition in Qom

The drinking water in Qom city is supplied from neighboring water basins transferred by inter-basin water transmission facilities and from water wells across the town. Water requirement in Qom was equivalent to 108 million cubic meters (MCM) and the collected TWW from two wastewater treatment plants (WWTPs) is about 23.8 MCM in 2013. Sharif Abad plain is located in the northeast of Qom. Annually, Sharif Abad plain is a destination for averagely 24 MCM of TWW of Qom, which is foreseen to hit 49 MCM in the 2025 program (Rahimi *et al.,* 2011)In Sharif Abad plain, the cultivated plants such as barley, alfalfa, cotton and pistachio that can resist saline water, but they need to be monitored. Due to the salinity of water with geo genic source and some level of contamination in Sharif Abad aquifer (containing major ions, TDS, B, TC, FC and FS are more than permissible limits) (Rahimi *et al.,* 2011) and expansion of wastewater collection system in Qom, the high volume of wastewater can be introduced as a significantly invaluable and dangerous source of water for development and management of agriculture and green space irrigation in Sharif Abad plain. The study area or the destination of wastewater and point sampling is shown in Fig. 1.

MATERIALS AND METHODS

Wastewater usage in agriculture should follow the standards to control the food and health security effects on the public and community. Pollutant parameters include temperature (T), turbidity (TU), total dissolved solid (TDS), total suspended solid (TSS), potential of hydrogen (pH), electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), some ions like magnesium (Mn), sodium (Na), sulfate (SO_4), chlorine (Cl), ammonium (NH_4), nitrate (NO_3), nitrite (NO_2), phosphate (PO_4), sulfide (S), sulfite (SO_3), cyanide (CN) and elements including iron (Fe), mercury (Hg), lead (Pb), chrome (Cr), cadmium (Cd), manganese (Mn), copper (Cu), nickel (Ni), arsenic (As), zinc (Zn), aluminum (Al), boron (B) cobalt (Co), fat, oil, grease (FOG) and detergents. Moreover, the biologic parameters including total and fecal coliforms (TC and FC respectively), fecal streptococci (FS) and Nematode (Ne) were investigated. In order to analyze the applicability of the TWW in Qom for irrigation and agriculture, the obtained effluent was sampled at the entrance to Sharif Abad plain monthly in a one-year period (Mar2013-Feb2014). EC, T, pH and DO were measured in situ. Na, K and heavy metals were measured by GTA Atomic Absorption Spectrometer (Varisn Autrulia brand). NO_3, NO_2, NH_4, PO_4, I, Br, SO_4 and CN were measured by Spectrophotometer (Hach American brand and DR/2800 model). EC, T, pH and DO were measured by multi parameter device (Hach American brand and Sension 156 model). TU was measured by turbidity meter (Aqualytic Germanic and AL450T-IR model). COD was measured by COD Reactor (WTW Germanic brand and CR 3200 model). BOD was measured by BOD measurement system device (WTW Germanic brand and OXI TOP IS12model) in Aryan Fan Azma Company (the trusted laboratory by the IRDOE).

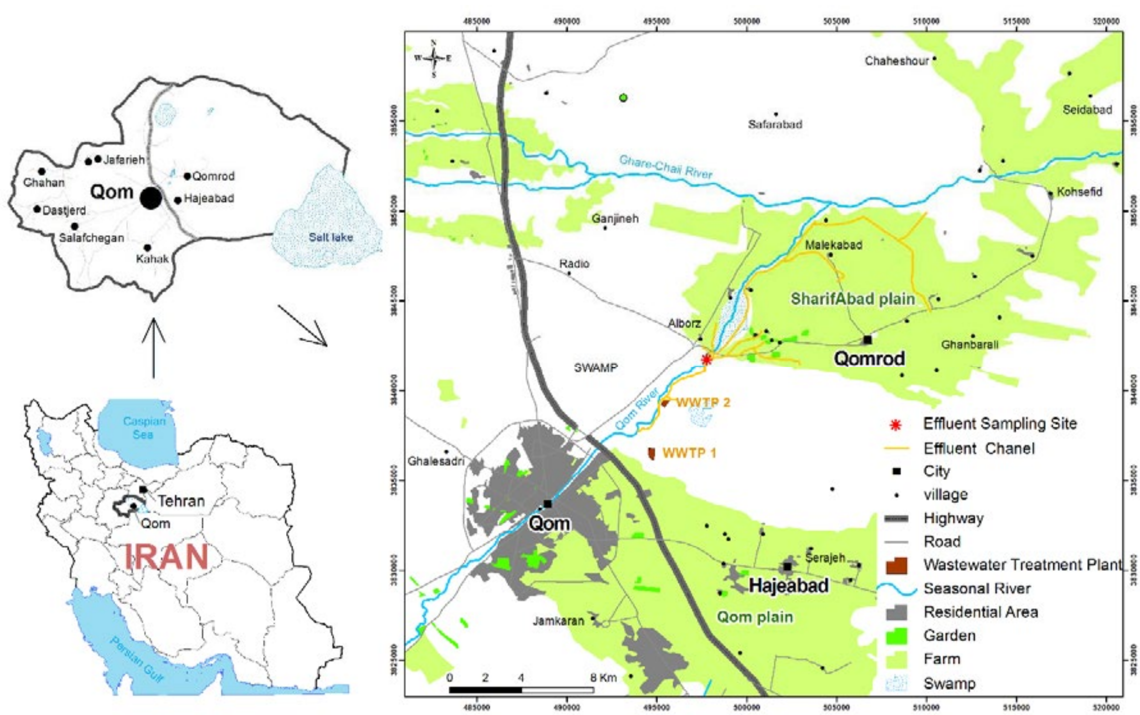

Fig. 1: The study area illustrating the sampling and destination of wastewater

Below are the results form analyses of parameters and elements in the form of tables and diagrams. The approach of visual presentation and understanding the result of sample analysis is very important (Freeze and Cherry, 1979). Standards that are used in the assessment of wastewater quality in Qom that cover TWW (monthly data collection) are shown by empty and blue triangle, IRDOE standards for discharge of wastewater into surface water (IRDOE surface water) are shown by continued and turquoise line, IRDOE standards for wastewater discharge into injection well (IRDOE-injection well) are shown by continued and brown line, standards for agriculture use (IRDOE-agriculture) are shown by disconnected and green line, WHO standards for agriculture use (WHO-agriculture) are shown by continued and green line, EPA standards for agriculture use (EPA-agriculture) are shown by disconnected and light green line and FAO standards for agriculture use (FAO-agriculture) are shown by point and light green line. In some cases that results might be under the laboratory detection limit, the detection limits are shown by continued and red line and by detection limit line name. In order to understand the quality condition of TWW from Qom (hydrochemical condition) Piper and Stiff diagrams have been used. These diagrams can help in determining the type, faces and sub alternation cation and anion of the wastewater.

There are different chemical parameters and factors for judging the degree of suitability of irrigation water quality. These standards include some factors that affect the plant growth, accumulation of elements in plant tissues, soil texture changes, and hydraulic behavior of water in soil. Most important of these chemical parameters are EC, sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium bicarbonate content (RSBC), residual sodium carbonate content (RSC), permeability index (PI), magnesium absorption ratio (MAR), Kelly's ratio (KR) and Wilcox diagram. The factors are used as indicators to carry out the assessments and are premised upon relations that are represented below (Gupta and Gupta, 1987; Kelly, 1951; Khandouzi *et al.,* 2015; Oladeji *et al.,* 2012; Richards, 1954; Todd and Mays, 2005). In all relations, values are expressed in mEq/L.

Electrical conductivity (EC)

EC, shows the degree of water mineralization, premised upon rock-water interaction and durability and is classified as tasteless, fresh, brackish, saline and brine. Based on the classification by the United States' salinity laboratory, irrigation water is classified as excellent (or low salinity class C_1 of <250 µmho/cm), good (or medium salinity class C_2 of 250–750 µmho/cm), permissible (or high salinity class C_3 of 750–2250 µmho/cm) and unsuitable (or very high salinity class C_4 of 2250–5000 µmho/cm).

Sodium adsorption ratio (SAR)

High concentrations of sodium concentration and salinity in wastewater can increase the exchange potential of soil (Muyen *et al.,* 2011). The importance of SAR content is due to decrease in soil permeability, increase in the soil hardness due to the replacement of calcium and magnesium by sodium in irrigation water, making soil saline and alkaline. The SAR index was applied to estimate sodium adsorption and exchange ratio by wastewater and to assess its suitability for irrigation (Richards, 1954). The index expresses the rate of sodium adsorption that is present in irrigation water. Usually, SAR in TWW is in the range of 4.5 to 7.9 (Feigin *et al.,* 1991; Muyen *et al.,* 2011). The ratio is calculated based on Eq. 1. Based on the classification offered by the United States' salinity laboratory, if SAR is in the range of 0-10, sodium rate is low and no disturbance is observed in the soil. If SAR is in the range of 10–18, sodium rate is moderate and long-term irrigation by this water is not suitable, and if SAR is in the range of 18–26, sodium rate is intensive and not suitable for irrigation. Eventually, if SAR is in the range of 26–30, sodium rate is very intensive and use of the intended water for irrigation is very dangerous and illegal.

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

Soluble sodium percentage (SSP)

Soluble sodium rate was applied to show the content and concentration of sodium in water sample and to classify irrigation water. This ratio is called SSP and can be calculated by Eq. 2 (Todd and Mays, 2005). Usually, the percentage of sodium exchange is increased with the increase of SAR as a linear relation (Muyen *et al.,* 2011). It is can lead to some complications in soil such as dispersion and rupture of soil structure, reduction in permeability and leaching, bogging and increase in evaporation and salinity (Muyen *et al.,* 2011).

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

The ions content of carbonate and bicarbonate in irrigation water can lead to increase in calcium and magnesium precipitation and to consequent increase of SAR in clay soil, increasing the salinity hazard (Khandouzi *et al.,* 2015). The phenomenon is investigated by empirical parameters including residual sodium carbonate content and residual sodium bicarbonate content. If carbonate and bicarbonate contents in water irrigation are higher than soil alkalinity, reduction of irrigation water quality would occur. Sodium carbonate in irrigation water is called black alkaline (it looks like a black spot on the soil surface, particularly in 8.5–10 pH) and can cause sodium enrichment and damage to physical properties of soil.

Residual sodium carbonate content (RSC)

RSC is actually the difference between the sum of carbonate and bicarbonate anions and the sum of calcium and magnesium cations as presented by Eq. 3. If RSC is lower than 1.25 m Eq/L (66.25 mg/L), use of the intended water is safe; if RSC is in the range of 1.25–2.5 mEq/L (66.25–132.5 mg/L), use of the intended water is doubted; and if RSC is 2.5 mEq/L (132.5 mg/L), use of the intended water for irrigation is unsuitable (Peiyue *et al.,* 2011). The *RSC* is calculated based on Eq. 3.

$$RSC = \left(CO_3^{\,2-} + HCO_3^{\,-}\right) - (Ca + Mg) \quad (3)$$

Residual sodium bicarbonate content

RSBC is actually the difference between carbonate and bicarbonate content. Permitted limit for RSBC is 250 mg/L (4.72 mEq/L) and the positive value indicates that dissolved calcium and magnesium ions are less than that of carbonate and bicarbonate contents (Bagheri *et al.,* 2013; Gupta and Gupta, 1987; Khandouzi *et al.,* 2015; Raihan and Alam, 2008). The parameter is calculated by Eq. 4.

$$RSBc = HCO_3^{\,-} - CO_3^{\,2-} \quad (4)$$

Permeability index

PI is a parameter to express the permeability problems of natural infiltration rate (Domenico and Schwartz, 1990). An index called permeability index was applied to express the quality of water in agriculture and irrigation along with the other indexes. This classification based on PI values are: class-1: PI >75, class-2: 25> PI >50 and class-3: PI <25 (Zahir Hussain and Mohamed Sheriff, 2015). In this classification, PI >75 is unsuitable for irrigation. The index can be expressed by Eq. 5.

$$PI = \frac{Na + \sqrt{HCO_3^{\,-}}}{Ca + Mg + Na} \quad (5)$$

Magnesium adsorption ratio (MAR)

MAR depends upon calcium and magnesium contents and is expressed as Eq. 6. Increase in this ratio equals to increase in magnesium content, which leads to increase in hydration and destruction of soil structure. Values above 50 are considered as risk index (Khandouzi *et al.,* 2015; Raihan and Alam, 2008).

$$MAR = \frac{Mg}{Ca + Mg} \times 100 \quad (6)$$

Kelly's ratio

KR is another parameter for assessment of water quality in agriculture and irrigation. It is similar to magnesium adsorption ratio and depends on sodium, magnesium and calcium contents and is expressed as Eq. 7. This factor classifies water as suitable (KR<1), marginal (1<KR<2) and unsuitable (KR>2) (Kelley, 1963; Kelly, 1951; Zahir Hussain and Mohamed Sheriff, 2015).

$$KR = \frac{Na}{Ca + Mg} \quad (7)$$

Wilcox diagram

Wilcox diagram is used for water classification as well as agriculture and irrigation. This diagram is based on salinity hazard (EC) and sodium hazard (SAR), classifies water into 16 classes, i.e. low, medium, high and very high, respectively on each axis. C is the sign of salinity and S is the sodium content.

RESULTS AND DISCUSSION

Analytical result

The results from analyses of the samples based on the applied standards are presented as maximum, minimum and average in Table 1. Knowing that the TWW from Qom is used for agriculture in Sharif Abad plain, it was assessment for agricultural and green space purposes. According to the national and international standards, TDS, TSS, TU, EC, Na, detergents, TC, and FC were found to be higher than

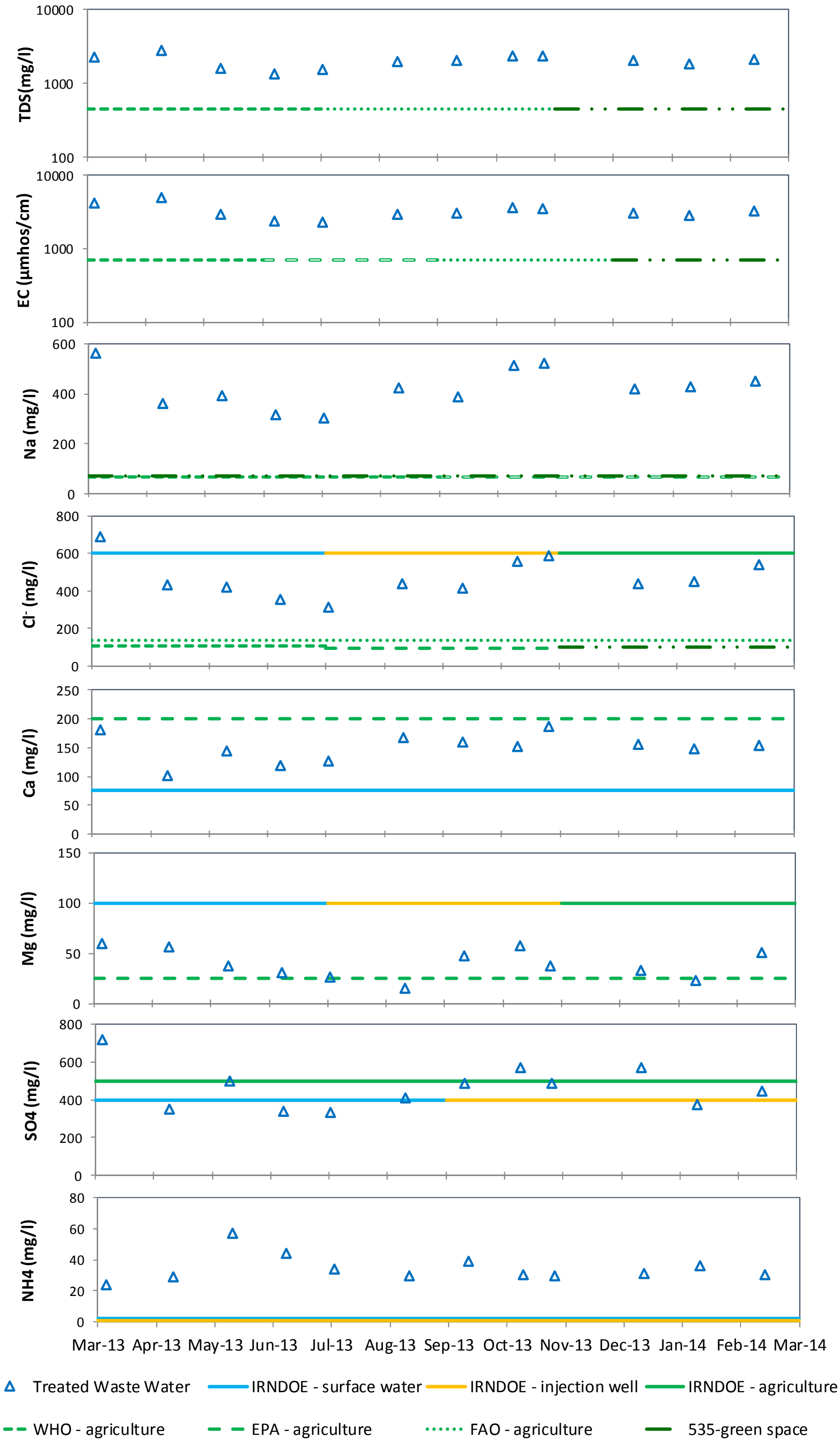

Fig. 2: Concentrations of TDS, EC, Na, Cr, Ca, Mg, SO_4 and NH_4 parameters in the collected samples compared to the applied standards

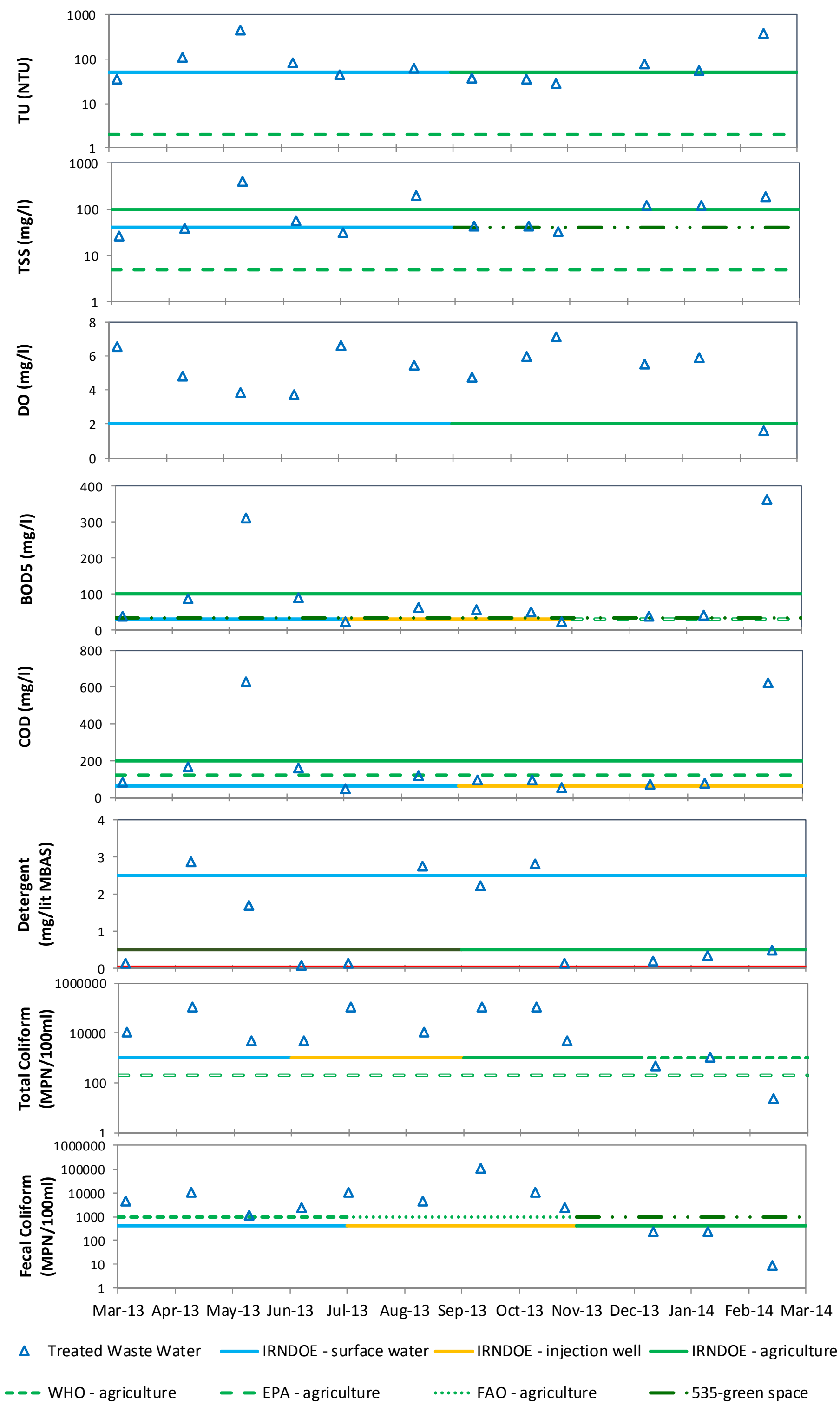

Fig. 3: Concentrations of FC,TC, detergents, COD, BOD, DO, TSS and TU parameters in the collected samples compared to the applied standards

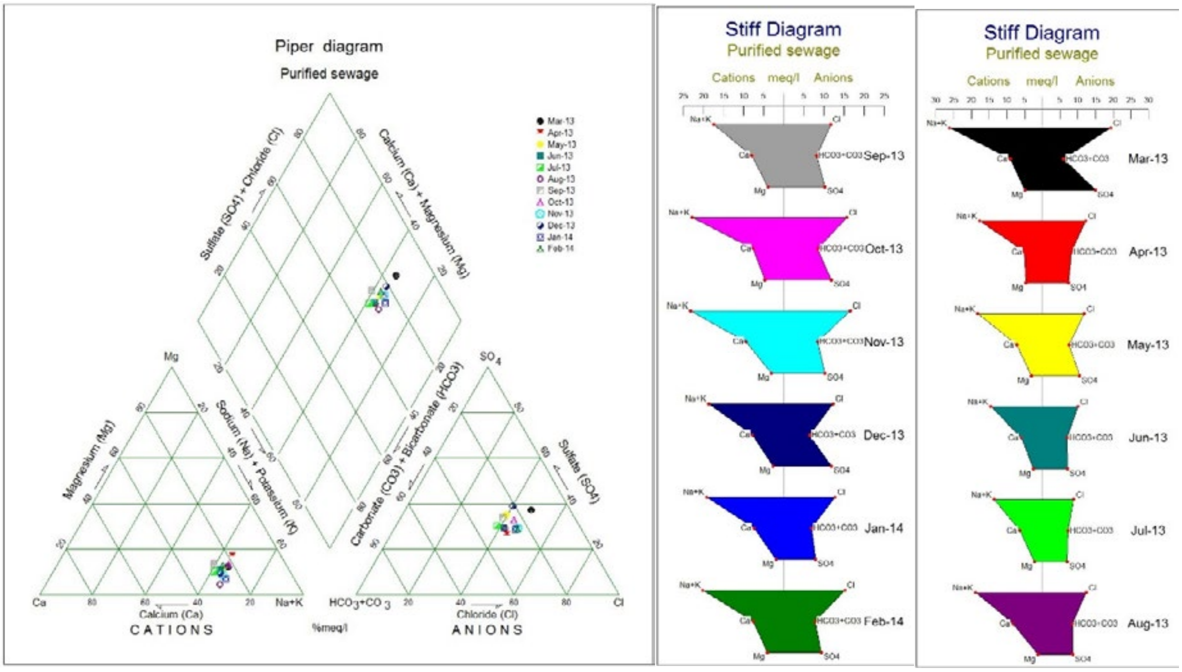

Fig. 4: Piper and Stiff diagrams of the samples collected from the treated wastewater in Qom

the permeable limit. TDS is a general criteria for understanding the quality of water for different usages in agriculture. TDS can decrease the permeability and hydraulic conductivity, changing the structure of soil particle (Huck *et al.,* 2000) and affecting the irrigation systems like clogged nozzles. The average TDS in the samples is 106 mg/L. Obviously, it exceeds the standard permissible limits that are used for agriculture, irrigation of green space, discharge into surface water and injection in wells for recharge. Also, EC is an important parameter in quality assessment of wastewater (WHO, 2006). The average of this parameter in the entrance of the study area is equal to 3216 µmho/cm. The maximum EC is proposed as 750 µmohus/cm in WHO standard, EPA Standard, FAO standard and Guideline Magazine (Issue NO: 535) for irrigation. Consequently, EC exceeds the standard permissible limit. High content of Na in water can incur damage to the tissue of root and stem and destroy the soil structure (Ayers and Westcot, 1985). The average Na concentration in the studied wastewater is 414 mg/L which is more than the limits recommended in EPA and Guideline Magazine (Issue NO: 535) standards. Fig. 2 shows the concentrations of TDS, Na and EC compared to the applied standards.

TU with average of 114 (NTU) in half of the sampling period is higher than the standard permissible limit. The average concentration of the studied detergents is 1.2 mg/L which is higher than standard permissible limit. Due to the variety of organisms in wastewater, measuring, monitoring and controlling them distinctly are very difficult, costly and time consuming. Therefore, considering the specific species (coliform bacterial), the contamination index has been used to determine the microbial quality of the TWW from Qom. Microbial quality of wastewater is influenced by different factors such as climate (temperature, sun light intensity, rate of precipitation, etc.), quantity and quality of the wastewater discharged into refinery, type of refining system, disinfection process efficiency, DO concentration (rise in dissolved oxygen can lead to deactivation of Escherichia coli and Enterococcus faecalis (Reed, S. C.; Crites, R. W.; Middlebrooks, 1995) and increase of death rate in FC (Marais, 1974) and pH) and pH increase which can decrease FC population. In addition, coliforms content can spread some diseases of bacterial, viral, radionuclide and parasitic sources (Danesh *et al.,* 2011). In the studied TWW, the total content of coliforms is averagely 40000 per 100 mL of water which is higher than the

Table 1: Measured and analized physico-chemical parameters in the treated wastewater from Qom

Parameter	Max	Min	Ave	IRNDOE			WHO	EPA	FAO	535- Green space	Detection limit
				Surface water	Injection well	Agriculture					
T(^{0}C)	30.8	11.5	21.2	*	-	-	-	-	-	-	-
TU (NTU)**	441	28	114	50	-	50	-	2	-	-	-
TDS (mg/L)**	2850	1345	2031	-	-	-	450	-	450	450	-
TSS (mg/L)**	389	26	106	40	-	100		5		40	-
pH	7.8	7.3	7.5	6.5-8.5	6_9	6_8.5	6_8.5	6_8.4	6_8.5	6.5_8	-
EC (ms/cm)	4850	2295	3216	-	-	-	700	700	700	700	-
DO (mg/L)	7	2	5	2	-	2	-	-	-	-	-
BOD_5 (mg/L)	364	24	99	30	30	100	-	30		31	-
COD (mg/L)	629	48	186	60	60	200	-	120			-
Mg (mg/L)*	59	15	40	100	100	100	-	25			-
Na (mg/L)**	520	301	414				66	66	-	70	-
SO_4 (mg/L)	720	335	467.5	400	400	500	-	-	-	-	-
Cl (mg/L)*	685	313.5	469	600	600	600	105	98	140	100	-
NH_4 (mg/L)	57	24	35	2.5	1	-		-	-	-	-
NO_2 (mg/L)	9.9	0.04	1.2	10	10	-		-	-	-	-
NO_3 (mg/L)	4.6	1	1.8	50	10	-	5	-	5	-	-
PO_4 (mg/L)	4.3	0.6	1.98	6	6	-	-	10	-	-	-
Detergent (mg/L)**	2.5	0.1	1.2	2.5	0.5	0.5	-	-	-	-	-
FOG (mg/L)	18	2.7	6.2	10	10	10	-	-	-	-	-
S (mg/L)	0.04	0.02	0.026	3	3	3	-	-	-	-	-
SO_3 (mg/L)	0.19	0.11	0.16	1	1	1	-	-	-	-	-
CN (mg/L)	0.003	0.001	0.0016	0.5	0.1	0.1	-	-	-	-	> 0.001
TC (MPN/0.1L)**	110000	23	40000	1000	1000	1000	1000	200	-	-	-
FC (MPN/0.1L)**	110000	9	21500	400	400	400	1000		1000	1000	-
Ne (MPN/L)	0	0	0	-	-	-	1	1	1	1	-
Fe (µg/L)	237	50	130	3000	3000	3000	5000	5000	5000	-	-
Hg (µg/L)	20	<2.0	< 5.4	-	Inconsiderable	-	-	10	-	-	-
Pb (µg/L)	< 50.0	< 50.0	< 50.0	1000	1000	1000	5000	5000	5000	-	< 50.0
Cr (µg/L)	< 50.0	< 50.0	< 50.0	50	1000	1000	10	10	10	-	< 50.0
Kd (µg/L)	< 30.0	< 30.0	< 30.0	100	100	50	10	10	10	-	< 30.0
Mn (µg/L)	122	30	75	1000	1000	1000	200	200	200	-	< 30.0
Cu (µg/L)	< 30.0	< 30.0	< 30.0	1000	1000	1000	200	200	200	-	< 30.0
Ni (µg/L)	< 30.0	< 30.0	< 30.0	2000	2000	2000	200	200	200	-	< 30.0
As (µg/L)	< 5.0	< 5.0	< 5.0	100	100	100	100	100	100	-	< 5.0
Zn (µg/L)	114	< 30	< 40	2000	2000	2000	1000	2000	2000	-	< 30.0
Al (µg/L)	< 50.0	< 50.0	< 50.0	5000	5000	5000	5000	5000	5000	-	< 50.0
B (µg/L)	620	210	450	2000	1000	1000	1000	70	70	70	-
Co (µg/L)	43	< 30	33	1000	1000	50		50	50	-	< 30.0

** = higher than permissible limit and * = close to high amount and permissible limit.

permissible limits in WHO and EPA standards. Also, the total content of fecal coliforms of averagely 21500 per 100 mL is higher than the permissible limits in the WHO, FAO and Guideline Magazine (Issue NO: 535) standards. Fig. 3 shows the concentrations of TU, detergent, TC and FC compared to the applied standards. Another significant point in this study is the NH_4 concentration. The results of analyzing the studied TWW show low and permissible amounts of NO_2 and NO_3, but very high NH_4 content (averagely 35 mg/L) exceeding the permissible limit. Nutrient (N and P) can act as a fertilizer to plants, but it should be noted that it may also contaminate the aquifer with nitrate. Therefore, it should be possible to reduce the use of chemical fertilizer (Moghadam *et al*., 2015). Normal concentrations of heavy metals are also observed in the NH_4 is an elementary part of the nitrogen cycle. It can cause water, soil and plants pollutions by entering into the nitrogen cycle. Therefore, consideration of environmental parameters which contribute to the reduction of pollution caused by nitrate accumulation, particularly in surface water and groundwater (Eutrophication risk), such as cultivation style, irrigation intervals, irrigation volume and thickness of unsaturated part overlying the aquifer, are very important. In spite of a thick soil layer above the water table (about 42 m) in Sharif Abad plain that can absorb the pollutants, NO_3 concentration is relatively high in a few wells in this area (Rahimi *et al.,* 2011) Knowing that the hydrochemical characteristics of the TWW in Qom can help in managing the way it shall be used, Piper and Stiff diagrams have been used to understand the quality conditions of the wastewater and to determine the type and faces of wastewater. The collected samples have cation sub-alternations of Na, K and Ca and anion sub-alternations as Cl, SO_4, HCO_3 and CO_2. Thereby, the type and faces of the TWW from Qom in order of abundance are sodium-potassium chloride. Fig. 4 shows hydrochemical conditions of the TWW from Qom by Piper and Stiff diagrams.

Assessment of quality parameters for agricultural purpose

EC, SAR, SSP, RSC, RSBC, MAR, PI and KR factors are calculated and the obtained results are shown in Table 2. Based on EC, all samples show very high salinity and unsuitable conditions for irrigation

Table 2: Assessment of quality parameters in the TWW from Qom for agricultural purpose

	EC	SAR	Na% (ssp)	RSC	RSBC	PI	MAR	KR
Mar-13	4070	13.05	64.52	-7.97	6.00	0.70	35.13	1.75
Apr-13	4850	10.03	63.10	-1.57	8.20	0.68	48.04	1.61
May-13	2960	10.64	64.00	-2.77	7.56	0.72	30.22	1.65
Jun-13	2390	9.60	63.00	-1.57	7.00	0.73	29.95	1.60
Jul-13	2295	8.92	61.23	-1.42	7.20	0.70	25.67	1.52
Aug-13	2905	11.80	66.20	-1.21	8.46	0.76	13.07	1.90
Sep-13	3020	9.72	59.40	-3.78	8.18	0.68	33.04	1.41
Oct-13	3590	12.65	65.00	-3.85	8.50	0.69	38.40	1.80
Nov-13	3496	12.80	65.10	-4.11	8.40	0.73	24.80	1.81
Dec-13	3010	11.25	64.00	-4.15	6.40	0.72	25.65	1.73
Jan-14	2790	12.20	67.21	-2.48	6.90	0.72	20.63	1.98
Feb-14	3220	11.35	63.02	-4.05	7.80	0.71	35.16	1.65

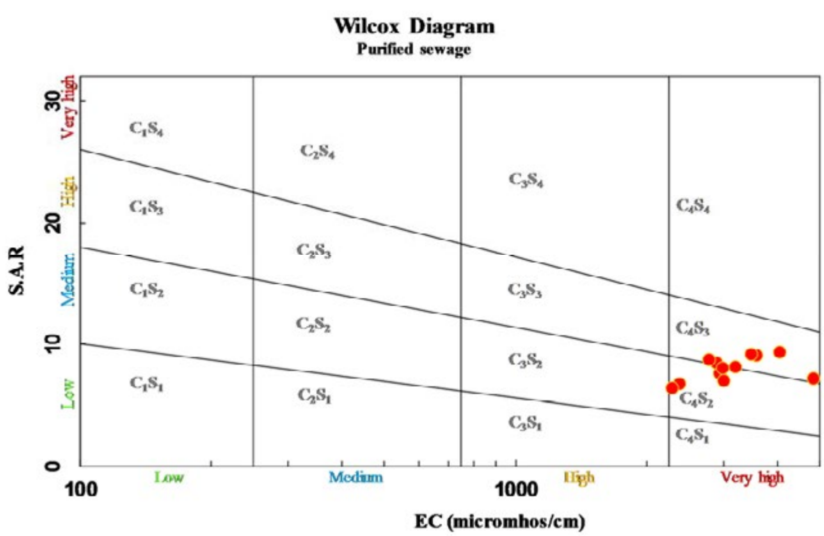

Fig. 5: Wilcox diagram of the samples collected from the TWW, showsing the medium to high sodium hazard and high and very high salinity hazards

usage. The results reiterate high potential of damage to plants, need for proper soil drainage and periodic irrigation with low salinity water. The SAR, which has been calculated according to Eq. 1, is desirable (SAR > 15) for all the samples. If SAR is in the range of 10–18, sodium rate is moderate and long-term irrigation by the intended water is not suitable. The SSP, which has been calculated by Eq. 2, is approximately above 60% in all samples and it needs to be monitored for salt accumulation in root zones. The RSC is calculated based on Eq. 3 and the obtained results show that it is lower than 1.25 m Eq/L, implying that water samples are suitable for irrigation. The RSBC, which has been calculated by Eq. 4, is higher than the permissible limit (4.72 mEq/L) in all the samples. The PI, which has been calculated using Eq. 5, is less than 75 in all the samples, indicating that suitability for irrigation use (PI >75 is unsuitable for irrigation). The MAR, which has been calculated by Eq. 6, is close to the 50 (values above 50 are considered as risk index) in all the samples except for Apr-13. The amounts of MAR are lower than risk index and suitable for irrigation. The KR, which has been calculated based on Eq. 7, has a marginal (1<KR<2) and nearly unsuitable condition (Table 2).

Wilcox diagram indicates that the water samples have medium to high sodium hazard and high and very high salinity hazards (Fig. 5). In addition to anions (Cl, SO_4, CO_3^- and HCO_3) and cations (Na, K, Ca and Mg), the concentration of some ions such as chloride and boron is important. Boron is also studied in the cultivated plants in a scientific literature. Boron in alfalfa (as a resistant plant) is 2-4 ppm and in cotton and barley (as semi-resistant plants) is 1-2 ppm.

CONCLUSION

Considering the increase of population, water and food demands, produced wastewater and related hazards as well as the decrease of quality and quantity of water resources (surface and groundwater) in the study area, investigation of water resources seem to be essential. In this study, the quality and quantity of the TWW from Qom for agriculture and irrigation purposes was investigated. The result proved that some parameters (TU, TSS, EC, Na, Detergents, TC and FC, NH_4, RSBC, KR and Wilcox diagram) are higher than the permissible limit and not suitable for agriculture and irrigation usage/purpose according to latest global standards and agriculture and irrigation usage indexes, respectively. The TWW from Qom had a normal concentration of heavy metals (unlike industrial wastewater, most urban wastewaters do not contain heavy metals), but the values of TC and FC in the studied wastewater was very high and exceeded the guidelines. It was found that application of the studied wastewater for agricultural purposes may pose risk to worker and consumers. The values of TC and FC in the studied wastewater were very high and exceeded the Iranian and WHO guidelines and normal in terms of heavy metals concentration. Wilcox diagram showed C_4-S_2 and C_4-S_3 (medium to high salinity hazards and high and very high sodium hazards) classifications. The NH_4 content in the TWW was higher than the permissible limit for recharging purposes. However, it can act as a fertilizer to plants, but it should be noted that it may also contaminate the aquifer with nitrate. It was found that the TWW was contaminated and required management and an action plan to manage it as a worthwhile source of water and to avoid environmental and health risks. The treatment and reuse of the studied TWW in the target plain (Sharif Abad plain) need to be reviewed in order to prevent probable contamination of Sharif Abad aquifer. The wastewater discharged into the environment would be more hazardous if used for agriculture and irrigation purposes.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

ABBREVIATIONS

Al	Aluminum
As	Arsenic
B	Boron
BOD	Biochemical oxygen demand
Ca	Calcium
Cd	Cadmium
Cl	Chlorine
CN	Cyanide
Co	Cobalt

CO_3	Carbonate
COD	Chemical oxygen demand
Cr	Chrome
Cu	Copper
DO	Dissolved oxygen
EC	Electrical Conductivity
EPA	US Environmental Protection Agency
FAO	Food and Agriculture Organization
FC	Fecal coliforms
Fe	Iron
FOG	Fat, oil and grease
FS	Fecal streptococci
HCO_3	Bicarbonate
Hg	Mercury
IRDOE	Iranian Department of the Environment
K	potassium
KR	Kelly's ratio
M	Magnesium
MAR	Magnesium absorption ratio
MCM	Million cubic meters
mEq/L	Mill equivalents per liter
mg/L	Milligram per liter
Mn	Manganese
Na	Sodium
Ne	Nematode
NH_4	Ammonium
Ni	Nickel
NO_2	Nitrite
NO_3	Nitrate
NTU	Nephelometric turbidity units
Pb	Lead
pH	Potential of hydrogen
PI	Permeability index
PO_4	Phosphate
ppm	Part per million
RSBC	Residual sodium bicarbonate content
RSC	Residual sodium carbonate content
S	Sulfide
SAR	Sodium adsorption ratio
SO3	Sulfite
SO4	sulfate
SSP	soluble sodium percentage
T	Temperature
TC	Total coliforms
TDS	Total dissolved solid
TSS	Total suspended solids
TU	Turbidity
TWW	Treated wastewater
WHO	World Health Organization
WWTP	Wastewater treatment plants
Zn	Zinc

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