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REVIEW

Urban wastewater reuse in agriculture for irrigation in arid and semi-arid regions - A review

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Abstract

Purpose In recent years, attempts have been made to compensate irrigation water shortage through widespread wastewater application as a low-quality water resource for agriculture. The existing wastewater treatment plants do not have sufficient capacity to treat such a huge volume of wastewater. In arid and semiarid region, soil type as well as climate is different from the others, so the aim of this paper is the review of literature on the effects of wastewater reuse in agriculture.

Methods An extensive literature review was conducted to evaluate urban wastewater effects on soil, plant and environment.

Results One of the best methods for wastewater disposal is wastewater discharge into the soil. However, as it was revealed in this research, in most cases, this method would lead to increased salinity, SAR, organic matter content, permeability, and electric conductivity as well as reduced soil bulk density. Nevertheless, wastewater effect on soil physical properties depends on its characteristics and also its application period. For instance, in durations less than one year, wastewater has often no significant effect on some soil properties such as bulk density. The best wastewater usage approach is utilizing drip irrigation method, which can overcome the shortcomings resulted from its application. In most studies carried out in this field, wastewater irrigation has led to increased accumulation of heavy elements and nutrients in the soil and even sometimes in under-cultivation plants. It is noteworthy that these elements' accumulation in the fruit section is less than their accumulation in the vegetable part of the plants.

Conclusion The use of wastewater without accurate management can extremely cause adverse environmental outcomes, including soil salinization, soil degradation, reduced soil hydraulic conductivity, soil hydrophobicity, poisoning, reduced yield of the crops, and surface/groundwater resources' contamination, and eventually the prevalence of diseases. Consequently, in order to reuse wastewater for agriculture, microbial contamination' reduction should be seriously considered in accordance with the standards determined by the Environmental Protection Agency or the World Health Organization guidelines. It is highly emphasized that after reaching the required standards, the wastewater can be used for irrigation. In conclusion, Pharmaceuticals presence in the wastewater are a growing global concern.

Keywords Pollution, Plant growth, Soil, Water shortage, Wastewater

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Introduction

Water scarcity problems are common in the arid and semiarid regions, which include the highly populated regions of the southwestern United States and most of the Middle East. Wastewater reuse is an option to increase available water supplies (Bichai et al. 2012).The causes of water scarcity are a combination of several problems: inefficient water distribution networks, no emergency plan to face decreasing rainfall and basic infrastructure, poor wastewater treatment, environmental resource degradation, and climate change (Urbano et al. 2017). Another cause of water scarcity is high demand of water irrigation and low irrigation efficiency.

The use of industrial or municipal wastewater in agriculture is a common practice in the world (Feigin et al. 2012). Studies have exposed that wastewater discharge into the soil is presumed as one of the best wastewater disposal methods. Meanwhile, wastewater acting as an environmental contaminant, it is indispensable to collect, treat, and then reclaim the wastewater into the water circulation within the nature using a sanitary method (Zolfaghari and Haghayeghi-Moghadam 2008; Rafi Al-Hosseini et al. 2010). Considering the high water demand rate as well as various water quality requirements, the agricultural sector can serve as an appropriate wastewater consumer. Since a long time ago, human being has been reusing and reclaiming water and wastewater for agricultural purposes. Dealing with a huge volume of the produced wastewater necessitates the attempt to seek a proper method for wastewater discharge in the environment. According to Wu et al. (2013), both treated water and raw wastewater are reused for agricultural irrigation as well as landscape irrigation. Nevertheless, studies uncover that raw wastewater discharge into the environment is associated with numerous health and environmental risks (Malekian et al. 2008).

Raw wastewater quality control has been prominently used for environmental protection in recent decades. In addition, wastewater treatment incurs the costs that might be increased based on the number of treatment stages. Having this in mind, many countries around the world, including the majority of developing countries, are not able to afford sufficient investment in this sector (Hussain et al. 2002). Wastewater reuse in irrigation would result in increasing agricultural production efficiency, surface water protection, reducing pressure on groundwater resources, and diminishing demand for chemical fertilizers, as well as decreasing wastewater treatment costs (Rosenqvist et al. 1997; Murray and Ray 2010; Ghorbani 2009). According to available information, wastewater has long been used for agricultural purposes in the suburbs of Isfahan over the 10th century. In the past, wastewater was commonly used to fertilize the lands; while, water shortage is currently the main reason for its application. The first urban wastewater treatment plant using an activated sludge method was constructed with the capacity of 480 m^2/day in Saheb Qaraniyeh of Tehran in 1961. The second one was constructed based on the stabilization pond method in Foulad Shahr, located in Isfahan Province of Iran in 1973. Presently, major cities across the country are generally equipped with a wastewater collection and treatment system or are passing the implementation stages' study.

Aerial images approve the assumption of abundant vegetation presence in the vicinity of the farmland-neighboring canals related to wastewater treatment plants (Mohajeri and Horrelman 2017). Wastewater is chemically different from freshwater, which is due to the presence of soluble organic matters in it comparing the freshwater. Adding wastewater-originated organic matter to the soil can alter its physical and chemical properties. Acknowledgements of the authorities and farmers as well as dealing with the dryness and a serious need for the reuse of wastewater and reclaimed water in agriculture have necessitated a large number of wastewater treatment plants to be designed and implemented across the country. Despite the history of wastewater reuse in the country, scientific research on its effects has practically started over the last two decades. In a part of the literature, the main focus has been dedicated to environmental consequences of utilizing these resources. In addition, some studies have addressed these waters' effects on the crops' quantity and quality. Currently, in many cities across the country, urban wastewater and surface runoffs are used in downstream farmlands, which can lead to increased proportion of the environment from healthy water resources (Allan 2001; Qadir et al. 2007). Wastewater production, collection, and treatment status as well as wastewater reuse rate in Iran in 2010 are presented in Table 1. As it can be seen, nearly 328 MCM of the wastewater (i.e. 40%) has been reused (Tajrishi 2011). Table 2 represents the country's development over the past years in terms of the wastewater system and the wastewater treatment capacity which clearly indicates the improvement of the wastewater treatment systems (Tajrishi 2011).

Table 1 Summarized status of produced, collected, treated, and reused wastewater in 2010 (Source: Tajrishi 2011)

Wastewater	Million cubic meter
Produced wastewater	3,547
Collected wastewater	1,162
Treated wastewater	820
Reused wastewater	328

Wastewater quality is continuously improving at an advanced level in Europe. At the moment, there are about 71000 wastewater treatment plants (WWTPs) in 28 EU member countries, Iceland, Norway, and Switzerland. Many of these treatment plants not only treat the urban wastewater, but also isolate organic contaminants including Polycyclic aromatic hydrocarbon (PAHs), Polychlorinated biphenyl (PCBs) and Polychlorinated dibenzodioxins (PCDD/Fs). Total wastewater treatment capacity corresponds to the population of 775 million individuals (www.recyclingportal.eu). Kuwait produces 600000 m^3/day of raw wastewater, 60% of which (about 375000 m^3/day) is treated up to the advanced level and the remaining amount (40%) is treated up to the tertiary level, i.e. the third level of treatment, through applying the activated sludge processes. Although the total daily wastewater production has been increased over the past years, the amount of wastewater discharged into the sea has been notably decreased (from about 65% in 2000 to about 30% in 2010). Fig. 1 shows the number of wastewater treatment plants in Iran. It is quite transparent that the number has been increased from 40 to 120 in only 10 years. It also demonstrates the increasing population connected to the network from 2 to 12.6 million people (Tajrishi 2011).

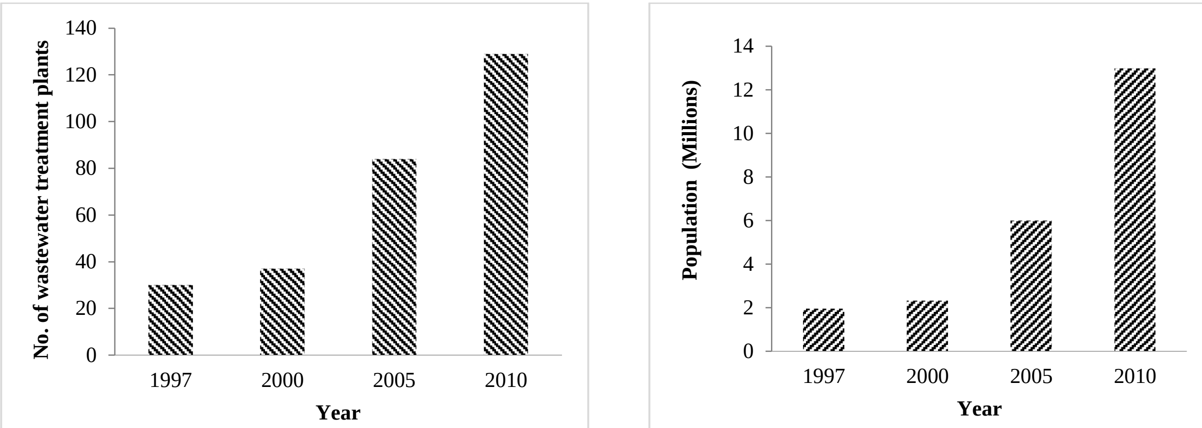

Fig. 1 The number of the wastewater treatment plants and the connected population to the network in Iran during 1997 to 2010 (Source: Tajrishi 2011)

The aim of this paper is to investigate the effects of the urban wastewater on the environment, human health, and the farmland irrigation, based on the case study of the Iranian experience. Moreover, this study evaluates urban wastewater effects on soil physical and chemical properties and also heavy metals' accumulation in soil and plants.

Wastewater impacts on soil physical properties

The use of the wastewater instead of the well water leads to the improvement of the soil physical properties and its sponge structure appearance. In more details, wastewater use usually affects the structure, porosity, permeability and saturated hydraulic conductivity of the soil (Tabatabaei et al. 2007). The extent of changes in a particular weight depends on wastewater application duration. For example, Arast et al. (2018) used wastewater for irrigation in Qom province for six months; nevertheless, no considerable change in specific weight was distinguished until the end of this period. Similarly, Masoudi Ashtiani et al. (2011) did not observe any changes in the soil bulk density in a short-term (3 months) wastewater use. In another study investigating the effect of long-term irrigation with treated urban wastewater on saturated hydraulic conductivity, Banitalebi et al. (2016) showed that irrigation with wastewater for duration of 13 years increased the value of Ks from 7 mm/h to 21 mm/h, which means that Ks has been tripled over this period although further irrigation with this wastewater did not increase the saturated hydraulic conductivity beyond this level. Also, in this study, wastewater positive effect on soil saturated hydraulic conductivity was demonstrated by soil improved structural properties (including strengthened and increased diameter of the soil aggregates, reduced bulk density, and increased porosity) (Banitalebi et al. 2016).

Alazba (1998) stated that TWW reduced the infiltration rate in Saudi Arabia. Also, the runoff ratio in freshwater was 7 percent and in treated water was 31 percent. Lado and Ben-Hur (2009) investigated the effects of irrigation with effluents on hydraulic properties of arid and semiarid soils. The increase of the effluents organic matter effects on the organic matter content of the topsoil, but it could lead to its decrease in the subsoil because of a “priming effect” of the effluent. The use of effluent for irrigation diminished saturated hydraulic conductivity (Ks). The amount of decreasing Ks depends on the effluent quality, soil chemical properties, and the soil porosity. Secondary effluent diminished the Ks of a loamy and a clay soil because of plugging of the pores with suspended solids, whereas the Ks of a sandy soil was not affected because of its large average pore size (Lado and Ben-Hur 2009).

Table 2 represents the changes in soil physical properties caused by urban wastewater use over 13 and 23 year periods by Banitalebi et al. (2016). As it is illustrated in Table 2, wastewater application in 13 years and 23 years was able to change actual density, bulk density, porosity and the average diameter of aggregates while irrigation with well water had no significant effect on these parameters. As it is seen, no changes were identified in soil actual density and instead soil bulk density was reduced with the use of wastewater. Therefore, it could be said that wastewater application in agriculture would lead to the reduction of soil bulk density and expansion of soil aggregates' stability due to increased organic matter content and intensified microbial activity.

Table 2 Soil physical properties affected by the long-term wastewater use (Source: Banitalebi et al. 2016)

Properties	Field 3 (Irrigation with wastewater for 23 years)	Field 2 (Irrigation with wastewater for 13 years)	Field 1 (Irrigation with well water)
Actual density (Mg/m3)	2.11[a]	2.15[a]	2.11[a]
Bulk density (Mg/m3)	1.04[b]	0.90[c]	1.25[a]
Porosity (%)	50.3[b]	57.9[c]	42.8[a]
Average diameter of aggregates (Mm)	0.93[c]	0.71[b]	0.54[a]

Similarly, Hassan-Oghli et al. (2005), Shirani et al. (2010), and Mahida (1981) have also reported the reduction in soil bulk density as a result of wastewater usage. Mojiri (2011) showed that municipal wastewater application caused a decreased of saline soil pH and bulk density as compared to control samples.

Nourmahnad (2013) added the wastewater sludge from the city of Shahrekord to the clay loamy soil and showed that adding large amounts of sludge changes the soil texture to sandy loam due to sand particles' presence in the wastewater sludge. Also, Arast et al. (2018) disclosed that wastewater treatment as well as wastewater integrated treatment and saline water would improve soil physical properties and fertility. The effects of salinity, sodium, and organic matter of treated wastewater on soil hydraulic conductivity are so complicated and depend on treated wastewater quality and soil properties. Generally speaking, wastewater usage leads to increased organic matter content and improves structure of the soil, which accelerates soil's hydraulic conductivity (Levy et al. 2011). Using urban and industrial wastewater of Khuzestan Steel Complex and comparing it with Karun River's water revealed the fact that increasing irrigation duration (number of years) with urban and industrial wastewater causes a significant increase in soil's water storage capacity during four to six months' irrigation period (Fig. 2a). Though, the effect of wastewater on this parameter was reduced at the lower depths (Fig. 2b) (Boromandnasab and Ghalambaz 2008; Saber 1986). Likewise, irrigation with the wastewater, in comparison with Karun River's water, caused a substantial increase in the soil's moisture content at the depth of 0-15 and 15-30 cm.

Tabatabaei et al (2017a) evaluated the effect of full irrigation (FI), traditional deficit irrigation (TDI) and partial root-zone drying (PRD) on water use efficiency (WUE) in corn cultivations using treated wastewater. The result showed that the dry and wet weight and LAI were maximum at FI and then PDR80 and finally TDI80 (including 80 percent water requirement). It also showed that the height of corn was high at FI and TDI80 than PRD80. Finally, wastewater application in the treatment named 5050-PRD80 (50% freshwater and 50% wastewater) and 5050-TDI80 compensated water deficit in WUE, LAI, and dry biomass percentage. It concluded that the PRD method was recognized more suitable than TDI in corn plants. In another study using three types of irrigation, the treatment soil hydraulic conductivity parameter reached 11.8, 7.6, and 5.2 mm/h by irrigation with raw wastewater, treated wastewater, and well water, respectively. This fact was uncovered through the comparison of the increased value of the mentioned parameter with its initial value (i.e. 3.1 mm/h) (Hassan Oghli et al. 2005).

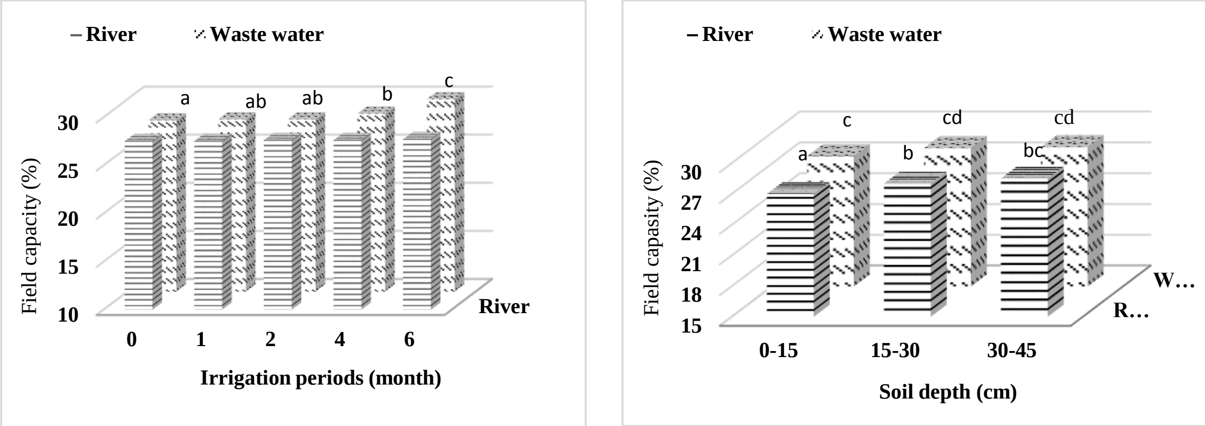

Fig. 2 The effect of water quality on the moisture content of the field capacity: (a) in different irrigation periods, and (b) at different depths (Boromandnasab and Ghalambaz 2008)

The effect of 9-year irrigation with the wastewater in the treatment plant located at the north of Isfahan was investigated and revealed that the wastewater irrigated field had less bulk density, final permeability and higher moisture content than the adjacent well water irrigated farm (Rouhani Shahraki et al. 2005). Drechsel et al. (2010) accentuated that the use of wastewater for 25 years increased the saturated hydraulic conductivity by 30%. Shahbazadeh and Amirinejad (2018) compared the physical properties of wastewater-irrigated soil with those irrigated with well water. According to the obtained results, the use of wastewater leads to improving stability of the soil aggregates and reducing bulk density as well as increasing the soil physical properties (saturated hydraulic conductivity, porosity percentage, and saturated moisture). These results were consistent with the findings of Mojiri and Abdul Aziz (2011).

Some other researchers have noted that increased wastewater sludge content would increase the soil saturated hydraulic conductivity and permeability as well as the stability of the soil aggregates (Hassan Oghli et al. 2005; Shirani et al. 2010; Mahida 1981). In contrast, the findings of Aiello et al. (2007) were different from these results. They used treated wastewater with sandy soil and drip irrigation in tomato farms over the growing season and reported reduced hydraulic conductivity, porosity, and water retention capacity along with the increased bulk density at the 0-30 layers.

Wastewater effects on soil chemical properties

As some elements' concentration in the wastewater exceeds the standard level, becoming gradually stored within the soil, these elements would change chemical properties of the soil and sometimes lead to the reduced farmlands' fertility and heavy metals' accumulation (Leili et al. 2010; Tabatabaei et al. 2017b). Some studies in this regard have reported salinity reduction of the saline soils as a result of irrigation with wastewater. One of these studies has demonstrated that wastewater irrigation with the salinity of 1.8 dS/m could reduce the saline-sodic soil salinity in studied region up to 1.52-2.54 dS/m. Moreover, lands' investigations in Barkhar County of Isfahan province showed that 7-year irrigation with wastewater not only kept positively the saline-sodic conditions of the soil, but also reduced the soil salinity level of the lands (Saffari et al. 2008; Erfani et al. 2002). Some other related studies have reported soil salinity increase parallel to wastewater use. For example, according to previous research, wastewater irrigation of wheat in the city of Zabol increased the salinity and soluble SAR of the soil in comparison with well water irrigation (Shirani et al. 2010; Ghanbari et al. 2007).

Salinization and/or sodification happen under irrigated agriculture, especially in lack of water and high evaporative demand areas of southwestern United States and other semi-arid regions around the world. Irrigation with wastewater change the physicochemical properties of soil and soil salinization. Soil salinization increases the osmotic pressure in the root zone and causes a limiting factor for plant growth and productivity (Elgallal et al. 2016). Some researchers emphasize that using TWW in lieu of FW increases salinity and change the soil's physical properties (Klay et al. 2010; Hasan et al. 2014). Insufficient precipitation in arid and semiarid areas causes salt accumulation that leads to diminish yield (Francois and Maas 1994; Munns 2002). In semiarid area with an annual precipitation higher than 508 mm, the rain isn't adequate to prevent long-term salt accumulation in the soil when irrigated with secondary TWW (Lado et al. 2012). Mandal et al. (2008) and Misra and Sivongxay (2009) stated that increasing the salinity caused a decrease of aggregate stability and hydraulic conductivity in poorly drained soil.

Besides, enlarging the concentration of the soil soluble salts with the use of wastewater was proved by Molahoseini (2014). Qishlaqi et al. (2008) assessed the consequences of the irrigation with wastewater in the farmlands adjacent to Khoshk River in Shiraz and observed an increase of 20-30% in the soil's organic matter content, an increase of 2-3 units in pH, a significant increase in calcium concentration and, as a result, in the cation exchange capacity (CEC), particularly in the upper layers of the soil. Hosseinpour et al. (2007) stated that due to wastewater irrigation of the soil piles, salt accumulation within the soil was gradually increased over the time. Also, the comparison of a 7-year irrigation of olive forests with well water and urban wastewater exhibited significant changes in the nitrogen, phosphorus, and potassium contents as well as EC and pH of the soil (Fig. 3) (Aghabarati 2006; Banitalebi et al. 2016) similarly showed that the irrigation with wastewater would reduce the pH value, which is due to increased organic matter content and oxidation during a long term (Beigi Harchagani and Banitalebi 2013). In the same way, Mathan (1994) stated a reduction of the soil's pH value due to the production of organic acids. Zamani et al. (2010) used 45 tons of the wastewater sludge produced by the factory polyacrylic products, which reduced the soil acidity by 1.8%.

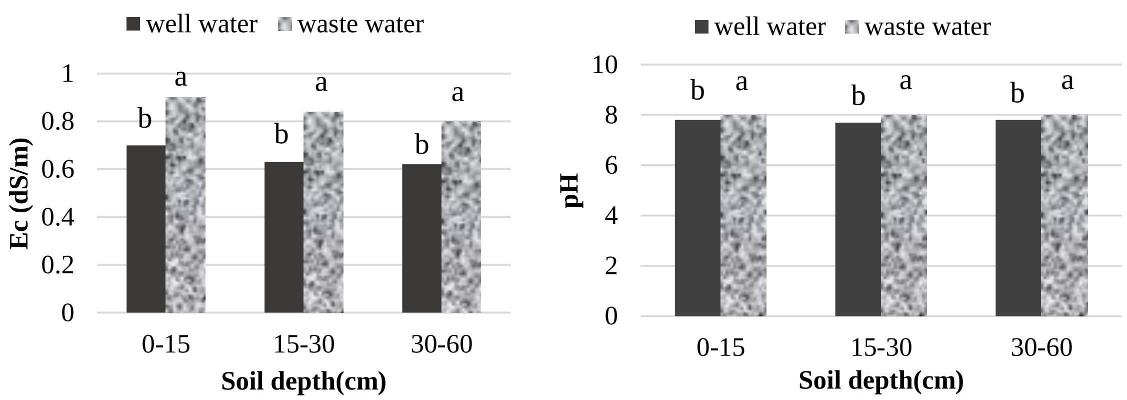

Fig. 3 Comparing EC and pH values of the soil in well water and wastewater irrigations (Source: Aghabarati 2006)

Alghobar and Suresha (2015) assessed the effects of irrigation with sewage water on some soil chemical properties at Meysor city, India. The results showed that the pH and EC, mean value of Ca, Mg, So_4, and also total nitrogen contents of sewage irrigated soil samples have increased as compared to control sample. Abegunrin et al. (2016) showed that soil Ph, Mg, K, Ca, TOC, TN, and CEC increased in wastewater irrigated samples at southwest of Nigeria.

Arast et al. (2018) also showed that the irrigation with saline water, brackish water, wastewater, combined wastewater and saline water at different depths, did not reveal any significant differences in terms of soil acidity; the only exception was the treated wastewater irrigation, which could be attributed to the presence of organic acids and acidifying compounds in the wastewater sludge (Bahremand et al. 2003). According to the results, the increased depth led to increased average acidity in all treatments, except the irrigation with brackish water. Therefore, it seems that further acidity reduction at the surface depth has led to decomposition rate increase in organic matter such as the nitrification and soil pH reduction process. The reason is that at this depth, the conditions are more suitable for entering air into the soil. In another study, two different treatments of raw wastewater and the treated wastewater in Parkandabad plant of Mashhad were considered. To do so, the columns were filled with sandy loam soil in both continuous and alternating flood conditions during seven 15-day periods and at three different depths of the soil (0-25, 25-50, and 50-100). The findings showed that the salinity values, SAR, nitrogen-nitrate, phosphorous-phosphate and total organic carbon, as well as two heavy metals of nickel and cadmium increased; in contrast, acidity of the soluble part of the soil was reduced due to wastewater alternative use in various soil depths (Hosseinpour et al. 2007).

Hassan Oghli et al. (2006) expressed the fact that the soil and plant together could absorb wastewater phosphorus by 97.2 to 99.9% and are able to prevent its transfer to the soil depth. A long-term irrigation with urban wastewater in Shahrekord city approximately doubled the organic carbon content of the soil; since, the wastewater in contrast to freshwater, contains some extent of organic carbon that is accumulated in the soil over the time (Banitalebi et al. 2016). Rattan et al. (2005) obtained similar results in this regard. García-Orenes et al. (2015) investigated the effects of irrigation with treated wastewater (up to 45 years) on soil properties and compared with irrigation with freshwater in semiarid agroecosystem. Their findings showed that irrigation with wastewater increased total organic carbon and available P significantly. The soil irrigated with treated wastewater had higher values of electrical conductivity (EC) than the soil irrigated with freshwater, whereas the soil pH decreased with WW irrigation.

Kebonye et al. (2017) investigated the treated wastewater impacts in semi-arid soils of Central Botswana. Four soil samples were collected along the treated wastewater channel and four samples on an adjacent well-drained channel (control). The findings showed that the soils had poor vegetation because of low organic matter, typical of arid and semi-arid environments (Aranda et al. 2011). Low rainfall, low nutrient status (CEC) and high rate of mineralization hinder biomass production and accumulation in soils. Although drainage in both classes was poor, nutrient status in treated wastewater affected soils were higher than in control soils attributed to the existing alkaline conditions. Heidarpour et al. 2007 applied two methods of irrigation (subsurface irrigation with porous pipe and surface irrigation) in Isfahan, central Iran, and investigated the effects of wastewater on soil chemical properties. The results revealed that the EC, Na and Mg of the soil at the depth of 0 –15 cm, under the subsurface irrigation method were significantly greater than surface irrigation method. The EC, Ca and Mg of second and third soil layers irrigated with wastewater were lower than with groundwater.

Wastewater effects on biological properties of the soil

Microbial biomass is an important factor in the process of soil organic matter dynamics and soil nutrient availability. Soil management practices affect the microbial biomass and in particular carbon substance input (Brookes et al. 1990). According to Nadi et al. (2011) the industrial wastewater from three paramount factories in Esfahan, Esfahan Steel Company-Zobahan-, Esfahan Mobarakeh Steel Corporation-Foolad Mobarakeh- and Esfahan Polyacryl Company was collected and used in silty clay soil. The results confirmed that industrial wastewater had significant effect on C mineralization and also untreated wastewater from Polyacryl Company increased C mineralization significantly. Other wastewaters diminished C mineralization or had not any significant effect on minerals. The effect of industrial wastewater on qCO_2 values was unstable. There was a decrease in qCO_2 during the first and second month of incubation period. (Kumawat et al. 2017) underlined that the amount of microbial biomass C, N and P declined with sewage water irrigation. They also demonstrated that soil microorganisms are considerably affected by heavy metals.

(García - Orenes et al. 2015) investigated the effects of irrigation with treated wastewater (up to 45 years) on soil properties and compared it with irrigation with freshwater in semiarid region. Their results showed that the urease, glucosidase, alkaline phosphatase and dehydrogenase activities and aggregate stability were higher in the soil irrigated with wastewater than in that irrigated with freshwater. The phospholipid fatty acid analysis showed a significant increase in bacterial abundance, particularly in G+ bacteria. The relative abundances of fungi, G− bacteria and actinobacteria were similar in the two soils. (Frenk et al. 2013) showed that relative abundance of Actinobacteria in a semiarid Mediterranean soil irrigated with TWW decreased. Their findings also showed that decreases in the relative abundance of the members of Actinobacteria and Firmicutes have been previously associated with amendments in soil organic matter, as (Elifantz et al. 2011) reported a higher increase in organic matter content in treated wastewater irrigated soils relative to soils irrigated with freshwater.

Al-Jaboobi et al. (2013) showed that treated wastewater increased EC, TDS, Na, K, P, N in soil samples. Also, higher population counts of total coliforms, fecal coliforms, staphylococcus aureus, yeast was observed in wastewater irrigated samples. Kavvadias et al. (2015) showed that disposal of untreated olive mill wastewater increased soil microbial properties such as microbial activity, microbial biomass carbon and metabolic quotient at the south of Greece. Kumawat et al. (2017) investigated the effects of sewage and dilute sewage water on soil biological properties at Jaipur city, India. The final results showed that microbial biomass, C, N, P, alkaline phosphatase and dehydrogenase activity decreased in light textured soils that have been irrigated with sewage and dilute sewage.

Wastewater and soil hydrophobicity

One of the side effects of long-term use of wastewater is the hydrophobicity emergence in the soil (Chen et al. 2003; Lerner 2003; Tarchitzky et al. 2007; Khashiboun et al. 2007; Arye et al. 2011). The modifying sludge increases the soil organic matter and at the same time reduces the soil moisture due to the presence of hydrophobic compounds (Ojeda et al. 2010). Emergence of soil hydrophobicity is a short or long-term dynamic process (Arye et al. 2011) and determines the time and space variations under frequent irrigations with wastewater (Arye et al. 2011). Hydrophobicity has been recently reported as a wastewater irrigation outcome by several researchers such as Chen et al. (2003), Lerner (2003), Tarchitzky et al. (2007), and Arye et al. (2011). In these studies, hydrophobicity has been limited to the upper layer of the soil, and the time of water penetration into the soil (WDPT) has been more than 240 secs, indicating a moderate degree of hydrophobicity. Wallach et al. (2005) observed a severe hydrophobicity (WDPT> 3600 S) in a citrus garden irrigated with wastewater. Their recent studies revealed that more than 20 years of hydrophilic soils' irrigation with wastewater has led to significantly increased hydrophobicity around the droplet outputs.

The role of sewage irrigation in the emergence of hydrophobicity and in different soil textures with or without vegetation has been studied in many inquiries. These studies have confirmed that the hydrophobicity is occurred in the surface layer at a medium to low level during the maximum water drip penetration time (WDPT) of 3 min (Arye et al. 2011). Nadav et al. (2013) evaluated the effects of wastewater irrigation on hydrophobicity and physicochemical properties of clay soil in an Avocado garden in Palestine and reported the hydrophobicity in plots irrigated with wastewater. A small wet area was observed around the droplets in these soils in comparison with the droplets using freshwater. Moreover, a dry area was observed under surface soil in the droplets of wastewater irrigation. The organic matter extracts derived from the plots were different in terms of the quality and quantity of organic matter in both treatments. Also, there were large amounts of hydrophobic matter in the extract of the soil irrigated with wastewater. In this study, low to moderate hydrophobicity (WDPT=60-80 s) was achieved in the plots irrigated with wastewater. The results of the study accomplished by Diamantis et al. (2009) showed that the short-term wastewater application had no effect on soil hydrophobicity.

Nourmahnad et al. (2015) also pinpointed the fact that although the use of wastewater sludge is a common method for soil reclamation and modification of the soil organic matter content, it may also reduce the soil moisture due to the presence of hydrophobic compounds. Nadav et al. (2011) stated that application of treated wastewater increased the hydrophobicity. They reported high degree of hydrophobicity in sandy soil treated with low degree of treated wastewater. Diamantis et al. (2013) showed that hydrophobicity in sandy soil decreased with using olive mill wastewater. However, the effects of long-term application have not been established. Abegunrin et al. (2016) showed that wastewater irrigation increased the soil hydrophobicity.

Heavy metals accumulation in the soil and plants using wastewater for irrigation

One of the major problems that should be considered when applying wastewater in farmlands is the accumulation of heavy metals in the soil as well as in cultivated plants (Mirzaei et al. 2013). In the same way, Bahmanyar (2007) stated that the use of urban wastewater in farms would increase heavy elements' content in the soil and cultivated plant. There are different kinds of heavy metal in effluent such as Pb, Cd, Ni, and Cr. Dadban Shahamat et al. (2017) measured the concentrations of heavy metals in wastewater and sludge wastewater treatment plant in Gorgan province of Iran. They disclosed that heavy metals' concentrations in wastewater effluent and dried sludge, except the returned sludge, were below the standards. Due to a long-term use of effluents, the necessity of other parameters' treatment, and negative effect of metals' bioaccumulation in sludge, their application for agricultural purposes should carefully reconsidered.

Aghabarati (2006) in his research pinpointed that the irrigation of forestry lands planted with an olive species for a period of seven years with two treatments of well water (the control) and urban wastewater would result in a significant increase in the nickel and chromium concentration of the soil (Fig. 4) and olive tree leaves although no significant difference was observed in heavy metals' concentration of olive fruits. The following figures compare heavy elements' accumulation at different soil depths in two mentioned treatments. As it can be seen, heavy elements' accumulation on the surface layer was more than their accumulation in lower layers of the soil. These results are consistent with those of Aghabarati et al. (2008).

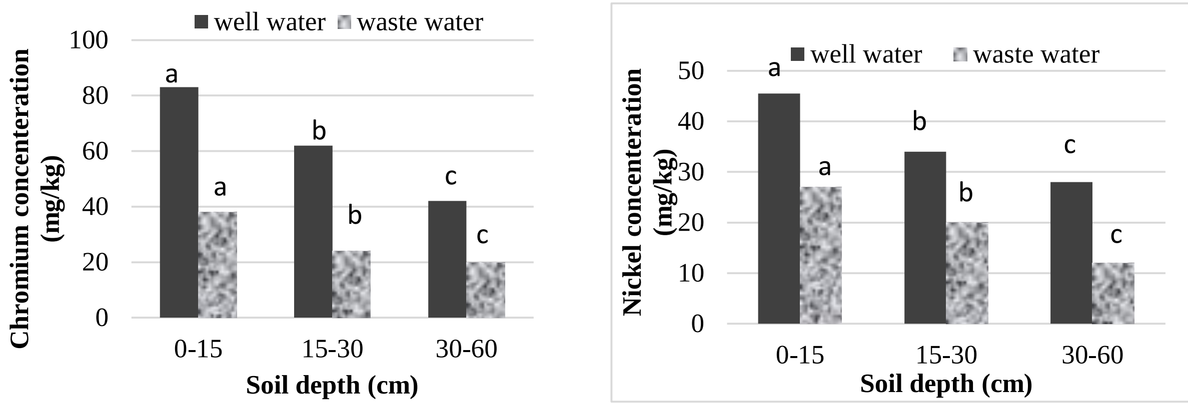

Fig. 4 Comparing chromium and nickel concentrations in the soil under well water and wastewater irrigation (Source: Aghabarati 2006)

* It should be noted that the comparison of wastewater and well water were performed separately

Heavy metals' average total concentration in the well water and wastewater samples used for Harsin farms' irrigation were compared by Shahbazzadeh and Amirinejad's (2018) study done in Kermanshah Province. They used parametric t-test and underscored that the total amount of heavy metals in the wastewater sample was significantly higher than its amount in the well water (Table 3). Presence of relatively high concentration of heavy metals in the wastewater sample along with the long-term (several decades) wastewater use for irrigation in farmlands can significantly increase the content of soil's heavy metals (Table 4). Similar results have been reported by many researchers as well (Rana et al. 2010; Manh Khai et al. 2008; Parsafar and Marofi 2013). Najafi et al. (2016) applied three treatments of clay pitcher including Clinoptilolite or natural zeolite (NZ), perlite (P) and vermiculite (V). One pitcher was placed beside each tree, at 50 cm depth and heavy metals (Fe, Cd, Cr, Cu, Pb, Mn, and Zn) were measured. The results showed that using substrates in this experiment provided the capacity for absorption of some heavy metals, especially Pb and Zn. However, increasing these two elements in the soil (Zn = 26 and Pb = 71 ppm) near the pitcher indicates that the substrates' absorption capacity was limited in high concentration of heavy metals in the wastewater.

Table 3 Heavy metals' concentration in well water and wastewater (mg/l) (Source: Shahbazzadeh and Amirinejad 2018)

Pb	Zn	Ni	Fe	Cr	Irrigation treatment
0.34	0.07	0.06	0.27	0.13	Well water
0.91	0.16	0.11	0.91	0.21	Wastewater
1	2	2	3	1	Allowed (Irrigation)

Table 4 Heavy metals' concentration in the lands under long-term irrigation with well water and wastewater (mg/l) (Source: Shahbazzadeh and Amirinejad 2018)

Wastewater	Well water	Treatment
91.3	83.9	Cr
1908.8	1417.5	Fe
72.8	58.0	Ni
66.4	47.7	Zn
94.8	83.4	Pb

Regarding geo-accumulation index Muller, all studied regions were uncontaminated (not contaminated with chromium, nickel, zinc, and iron). The findings represented that contamination degrees were detected only for the lead and varied from slightly contaminated (under well water irrigation) to very contaminated (under urban wastewater irrigation) (Shahbazzadeh and Amirinejad 2018).

Qishlaqi et al. (2008) evaluated negative effects of irrigation with wastewater on the soil and sample crops along the Khoshk River located at the suburbs around the city of Shiraz, Iran. For this purpose, the samples were collected from the soil profile (depth of 0-60 cm) and the products were collected from two different areas irrigated with wastewater and freshwater (as the control). They obtained the total concentration of five heavy metals including Ni, Pb, Cd, K and Zn. It was uncovered that the use of untreated wastewater increases heavy metals' content (in particular Pb and Ni) beyond the maximum permitted level (MPL) in the upper soils. Some Cd-containing vegetables (e.g. spinach and lettuce) were contaminated due to their high physiological accessibility in the upper soils. Also, the long-term wastewater use brought about over-accumulation of nickel and potassium in the wheat crop.

Kebonye et al. (2017) determined the effect of irrigation with wastewater on soil heavy metal accumulation in semi-arid soils of Central Botswana after 20 years. Soil samples were collected from eight sites: four along the treated wastewater channel and four on an adjacent well-drained channel (control). Particularly, mean heavy metal concentration in the two drainage classes did not vary significantly ($p > 0.05$). Most of the mean heavy metal concentration levels per drainage class were generally below internationally allowable limits suggesting minimal influence from the discharged treated wastewater. These concentration levels were further explained using various soil properties (e.g. pH, EC, OM, CEC).

Another study was performed by Choopan et al. (2018) in Torbat-e Heydarieh' farmlands which have the sandy loamy soil with 7.5 acidity and organic materials of 0.6%. They conducted a plan including three different treatments including well water, sugar factory wastewater, and integrated well water and wastewater (with 1:7 ratio) in barley plant with two irrigation levels, namely complete (100%) and 75% water stress. The results revealed that stress variations at 1% level had significant effects on the plant's height, the seed yield, and the root length. The maximum seed yield was observed in the control treatment and the minimum seed yield was observed in the treatment of sugar factory wastewater at the 75% water stress level. Furthermore, the highest plant height was obtained in the control treatment. In the same manner, Shahbazadeh and Amirinejad (2018) compared the concentration of heavy elements in the soil under well water and wastewater irrigation and demonstrated that the zinc and iron contents were significantly higher in wastewater irrigated lands than the lands under well water irrigation while chromium, lead, and nickel showed no significant differences.

Alghobar and Suresh (2015) showed that the P, Ca, Na, K, TN (total nitrogen) contents in sewage irrigated tomatoes were significantly higher than control samples. Salehi and Tabari (2014) in their research investigated the effect of urban wastewater on pine trees and soil properties and found that the concentrations of N, P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn as well as the values of pH, EC, SOC, and CaCO in the needle leaves of the pine trees irrigated with wastewater were significantly higher than the ones which were cultivated under well water irrigation. In the study carried out by Cheshmazar et al. (2018), the concentration and risks of heavy metals (Zn, Mn, Cu, Cr, Cd, and Pd) in the soil, water, and vegetables were obtained and evaluated from groundwater irrigated and wastewater irrigated farms in Bushehr city of Iran. The variation process of heavy metals' concentration was as Mn> Zn> Cu> Pb> Cr> Cd. According to European standard, with the exception of cadmium and lead, the concentration of other heavy metals was within the permitted range. Besides, the content of heavy metals in the farms irrigated with wastewater (FWW) was significantly higher than their content in the farms irrigated with groundwater (FGW) ($P < 0.05$) (Table 5).

Table 5 The comparison of average concentration of heavy metals in the soil (mg. kg^{-1}) and water (μg.L^{-1}) used for irrigation (Source: Cheshmazar et al. 2018)

Heavy metals	FAO Standard (Areys 1985)	Irrigation water of FGW	Irrigation water of FWW	EU Standard (2006)	Farm irrigated with groundwater(FGW)	Farm irrigated with wastewater(FWW)
Zn	200	78.53	121.73	300	47.71	68.75
Mn	20	8.24	23.32	2000	196.12	277.62
Cu	17	9.27	17.66	100	18.31	32.68
Cr	550	23.84	53.25	100	17.09	42.19
Cd	50	4.31	7.63	3	0.87	1.76
Pb	65	12.84	27.29	100	5.83	12.04

FGW: Farm irrigated with groundwater, FWW: Farm irrigated with wastewater

The lands under eleven types of vegetables' cultivation, located at the southern part of Tehran, were irrigated by urban wastewater for four consecutive years. The investigations revealed that heavy metals' content of the soil were elevated beyond the permitted level, in which chromium and cadmium had a more critical status (Torabian and Mahjori 2002). Moreover, Gupta et al. (2012) examined heavy metals' accumulation in vegetables grown in the farms irrigated with wastewater for a long time. The obtained results pinpointed that spinach and radish had the highest concentration of lead, zinc, and cadmium, indicating the ability of these plants to absorb heavy metals. Lente et al. (2014) also detected the same result. By evaluating heavy metals-induced contamination in the vegetables irrigated with wastewater, they found that wastewater irrigation could lead to heavy metals' accumulation in the soil. Therefore, excessive use of wastewater for irrigation can also cause contamination in vegetables. Another research also uncovered that the rice farms' irrigation with urban wastewater in the west of Sari and the center of Ghaemshahr intensified the content of cadmium, nickel, lead, and chromium in soil. Amplifying the use of wastewater instead of well water resulted in lead concentration increase in both soil and plant (Moradmand 2008). Using industrial wastewater for the irrigation of Hordeummorinum specie caused that the concentration of zinc, lead, and nickel in the soil and plant samples goes beyond the FAO standards. However, these elements' concentration in the plant was reduced from the beginning of the growth season to the end (Zolfaghari and Haghayeghi-Moghadam 2008).

In the irrigation of Canola with urban wastewater, the concentration of soil's heavy metals was higher in the treatments irrigated with additional wastewater (Taqavi et al. 2009). Using urban wastewater for the irrigation of green and red beans discovered that heavy elements' accumulation in these two plants was at a desirable level with regard to the average global standard (Saffari et al. 2008). In a case study accomplished in Kish Island, sludge application at growth early stages declined the plant's growth; nevertheless, after five months, due to spring rainfalls and reduced salinity of the soil samples treated with sludge, a significant increase in the plant's growth was occurred. Also, due to the sludge application, an increase was observed in the content of essential micronutrient elements (iron, manganese, zinc, and copper) as well as nutrients in the soil and leaf samples (Shafieepour et al. 2011). Feyzi and Rezvani (2008) also showed the wastewater increased the yield and the harvest date of fresh forage as well as the yield of dry cheap forage and finally reported a statistically significant increase in mentioned issues. Based on their findings, the content and yield of protein in the forage irrigated with 75% of wastewater were higher than other treatments. It was luckily found that the irrigation with treated wastewater under the conditions of this experiment had not any adverse effect on the soil and plant in terms of health and contamination with heavy elements (lead and cadmium). (Mohammadi et al. 2010) proposed the use of adsorbents such as rice husk and leaf compost as an effective approach for removing heavy metals (copper, nickel, zinc, and chromium) from industrial wastewater.

Some researches indicated no effects of wastewater on heavy metal accumulation in soil. For example, Hussain and A1-Saati (1999) pointed that the short- and long-term uses of different types of wastewaters for irrigation didn't have any significant increase in the bioaccumulation of heavy metals in crops and soils. However, wastewater can reuse in agriculture after appropriate treatment and some management practices such as leaching requirements, proper crop selection, estimation of plant water requirements, adoption of improved irrigation methods and application of right amount of fertilizer. In another experiment, Wang et al. (2003) evaluated the effects of wastewater on 29 physicals, chemical, and biological properties of soils which irrigated by wastewater in Bakersfield. Total porosity, pH, EC, Mg, P, and Zn of soils in the control and the treated fields were measured. There was no significant difference in all of the soil parameters in control and treated fields except for the total porosity and Mg. Abedi- Kopaei et al (2006) showed that concentration of Pb, Mn, Ni, Co increased in soil samples of Borkhar region, Isfahan, that was irrigated by treated wastewater.

Mojiri (2011) showed that municipal wastewater application increased the EC, P, OM, TN, K, Na, Cl, Fe, Cd and Zn contents in saline soil. Al Omron et al (2012) studied the long-term effects of irrigation with treated sewage on some of the soil chemical properties and heavy metals concentrations in the soils of the date palm at Al- Hassa Governnovate, Saudi Arabia. The results showed that the heavy metals' contents and organic matter in sewage irrigated soils' samples have increased. Heavy metals' content of soil increased from 17% to 30% in sewage-irrigated soil samples as compared to well water irrigated and the pH of sewage irrigated soil samples dropped by 0.3 Ullah et al. (2012) investigated the effects of sewage water on some properties of soil and plant (Spinach) at two sites of Peshawar city, Pakistan. In sites A and B, sewage water was used for irrigation more than 15 and 35 years, respectively. The final results showed that the concentration of Pb, Cr, Cd, Cu, Zn, Ni increased in contaminated soil sites and spinach leaves compared to well water irrigation site.

Wastewater and the environment

Having very complex physical, chemical, and biological properties, soils play a very important role in improvement of the quality of contaminants, including wastewater. Regarding the quality and type of wastewater used in irrigation, it seems that the soil is capable of reducing the contaminated bacteria for human use (Shaygan and Afshari 2004; Gallegos et al. 1999; Campos et al. 2000; Tillaman and Surapaneni 2002). Through direct discharge of the raw or treated wastewater, detergents take the opportunity to enter the environment and reduce water quality by water resources' contamination. The methods used for sludge treatment depends on the size, type, the location of treatment plant, operation of the treatment plant's units, properties, amount of the solids, and the final sludge disposal. In any case, the adopted method should economically convert the received sludge into the materials which are not prohibited to be disposed in the environment.

The conventional method of raw sludge treatment is commonly performed through two various ways called anaerobic digestion and aerobic digestions. The sludge treatment reduces the required biological oxygen, the content of solids, and odors; though, it is not always effective in pathogens' reduction (Yousefi et al. 2018). In another study accomplished at the inlet raw wastewater from Shahrak-e Ghods, Mahvi et al. (2004) reported the BOD5 values of 202 mg/l in the raw wastewater and 18 mg/l in the outlet, which showed the average removal of 91.1%. Also, the COD value was found to be 283 mg/l in the raw wastewater and 22.8 mg/l in the plant's discharged wastewater, indicating the average removal of 91.9%. Since detergents are made from chemicals, and the BOD5 and COD contents are considerably reduced in the wastewater, the efficiency of the activated sludge system in Shahrak-e Ghods treatment plant can be approved.

Mahvi et al. (2004) compared high removal efficiency of detergent with the wastewater in activated sludge system and achieved discharge standard into the environment. They observed that the amount of detergent in the output wastewater was lower than the discharge standard into the surface water (1.5 mg/l) and the discharge standard into the groundwater (0.5 mg/l); thus, there is no need for the treatment advanced level. Mohammadi et al. (2018) prepared some samples from the wastewater treatment plant in Shokohieh Industrial Park, Qom Province, during four seasons (winter, spring, summer, and autumn). Their results underlined good physical properties and quality of sludge for the food production and inappropriate quality in terms of phosphate contamination. According to the t-test, the amount of fecal and total coliform varied from the cold to hot seasons ($P < 0.001$). This study accentuated that sludge is placed in the class B (EPA standard) and due to this, it is not suitable for diverse applications such as grass, playgrounds, farmlands and forestry lands.

Najirad et al. (2018) determined the total and soluble amounts of iron, zinc, lead, cadmium, cobalt, copper, manganese, and nickel elements in the sludge prepared from three wastewater treatment plants in Shahrak-e Gharb, Ekbatan, and Shoush areas of Tehran province and compared them with the global standard values. Based on the obtained results, a total of 0.01% of the whole studied metals was soluble, 1.32% DTPA-was extractable, and 98.76% was inaccessible. Among the three studied sludge samples, the samples of Shoosh, Ekbatan, and Shahrak-e Gharb plants had a total amount of heavy metals equal with 73.39, 42.28, and 95.22 (g/kg) of the sludge dry weight, respectively. Given the high amounts of zinc and copper in the sludge samples, in comparison with the standard level, the sludge samples of the studied treatment plants were not included in the exceptional quality group that is applicable in agriculture. Furthermore, a comparison of coliforms' population with relevant standards showed that the entire sludge of the treatment plants was classified in group B, in which its application in agriculture is limited. In a research, it was focused on parasites' identification in wastewater sludge.

Yousefi et al. (2018) extracted some samples from industrial wastewater in Babolsar, located at the north of Iran, and compared their concentration with EPA standards. The sampling was performed in four sludge storages within the six months and totally nine samples were taken from each storage. The investigations uncovered that the number of the parasite eggs was significantly higher than their numbers based on EPA standard. By examining the wastewater quality of Arak Treatment Plant, Rahimi et al. (2017) reported that the quality of the wastewater of the treatment plant has been improved over the last five years and even it has reached a desirable level one year before the study implementation. Interestingly, although wastewater lacked a good quality in 2012 and could be only used for green space and forage production, its improved quality made it applicable for industrial use, green space, forage production, and oilseed production as well. They also proposed standards for each application according to the fuzzy method and entropy technique, as described in Table 6.

Table 6 Standards proposed by Rahimi et al. (2017): an integration of Iran, FAO, and WHO Standards

Type of use	Egg parasite	Al	Cr	Pb	Hg	Cd	As	pH	NO_3	PO_4	TSS	Ca	Mg	Fecal coliform	TDS
Livestock forage and meadow	1	5	1	1	0.001	0.05	0.1	6	50	20	250	400	60	1000	2000
Cooked vegetables and oily seeds	1	5	1	1	0.001	0.05	0.1	6	50	6	250	400	60	1000	400
Green space	1	5	1	1	0.001	0.05	0.1	6	25	15	50	400	60	1000	2000
Surface water	1	5	0.5	1	0.001	0.1	0.1	6.5	50	6	40	75	100	1000	500
Artificial nutrition	1	5	1	1	0.001	0.1	0.1	5	10	6	250	200	100	1000	400
Industry	1	5	2	1	0.001	0.05	0.1	6	50	20	120	75	100	1000	1000

All units except Fecal coliform (N/ 100mgr) are in (mg L^{-1})

The results of the experiments illustrated that the wastewater produced from secondary treatment can be used for planting without any concern about environmental contamination; so, it can even improve trees' growth in some cases. Compared to the surface drip method, the sub-surface drip method incurred less biological contamination to the surface soil; thus, it can reduce the concerns about workers' direct contact with the surface soil. Fig. 5 displays the effect of wastewater irrigation on fecal coliforms' population (Fig. 5a) and total coliforms (Fig. 5b) and on the soil surface layer (0-5 cm). For this purpose, five methods were utilized including: Furrow irrigation with well water (FN), surface drip irrigation with wastewater (DI), sub-surface drip irrigation with wastewater at the depth of 15 cm (SDI_{15}), sub-surface drip irrigation with wastewater at the depth of 30 cm (SDI_{30}), and Furrow irrigation with wastewater (Tabatabai and Najafi, 2009).These findings indicate the suppressive effect of sub-surface drip irrigation on the soil surface contamination which was consistent with the results of other researchers in similar conditions (Hassanli and Javan 2006; Mostafaizadeh et al. 2005; Najafi et al. 2006; Oron 1999; Palese et al. 2009).

In Rouhani Shahraki et al. (2005) study, the treated wastewater of Dolatabad area of Isfahan was beyond the Iranian standard level in terms of chemical oxygen requirement and suspended matter. In sum, the salinity, alkalinity, sodium, and lead content of all wastewater treatments were higher than well water treatments in that region. Unluckily, all the treatments were far below the standard level in terms of lead contamination. Campos et al. (2000) stated that in their research, only one day after irrigation with wastewater, the pollution of coliforms significantly reduced. This indicates that the soil is able to diminish the pollutant bacteria when the quality and type of the wastewater used for irrigation is appropriate. Asgari and Albaji (2017) examined the possibility of using wastewater in Shahrekord city based on the observation of fecal coliform and the number of intestinal nematodes and they concluded that wastewater usage for irrigation of plants that can be directly eaten raw (un-baked) would not be recommended. Farhadkhani et al. (2018) measured the total and fecal coliforms and Escherichia in secondary treated wastewater (STWW), irrigated soil and harvested crops. Except for EC and sodium adsorption ratio (SAR), which were slightly higher in STWW soil samples, there was not significant difference on physicochemical properties of the soil irrigated with STWW in comparison with control plots. A little concentration of E. coli was found in soil which was irrigated by STWW. There was no microbial contamination in terms of E. coli on harvested maize and onion. E. coli contamination of lettuce and spring onion was found for both irrigation schemes.

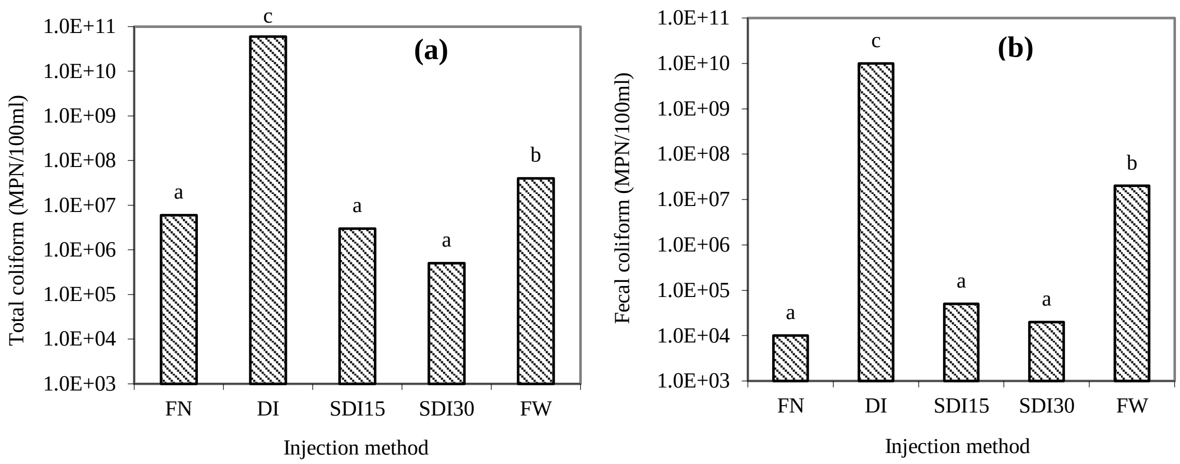

Fig. 5 The population of fecal coliforms and total coliforms (MPN/100 ml) at the surface layer of the soil (0-5 cm) (Source: Tabatabaei and Najafi 2009)

In the other study which carried out by Lonigro et al. (2016), soil microbial contaminants were investigated. These assessed contaminants comprised of: fecal coliforms, Escherichia coli, Salmonella, Protozoa giardia, Cryptosporidium, and vegetables irrigated with urban wastewater. They demonstrated that irrigation with urban treated wastewater was generally possible and despite the high concentration of these contaminants compared to Italian standard, the quality of products and soil showed no problem associated with fecal contamination. They concluded that urban treated wastewater used for irrigation did not expose the human health to hazards but Pereira et al. 2002 emphasized that to avoid health hazards and damage to the environment, wastewater must be treated to reach the standard level before it can be used for irrigation. Al-Omron et al. (2012) showed that sewage effluents had higher concentration of Pb, Zn, Cu, Co, Cr, As, Cd, Fe, Mn, Ni compared to well water. Sou/Dakoure et al. (2013) showed that the structure of subsurface layer of soil was damaged in industrial treated wastewater irrigated samples resulting in reduced infiltration rate. Also, a black deposit was observed on the soil surface because of alkali formation. Gatta et al. (2015) showed that the composition and dynamics of bacteria population in soil was affected with using the treated agro-industrial wastewater compared to groundwater.

Wastewater effects on plant yield

Wastewater is a valuable source of nutrient elements as well as organic matter required by the plant in order to achieve soil fertility (Aghabarati 2006; Tabari et al. 2007; Moradmand 2008; Meli et al. 2002; Ramirez et al. 2002; Rattan et al. 2005). Hussain and A1-Saati (1999) indicated that reuse of wastewater in Saudi Arabia as a supplemental irrigation increased crop production, water use efficiency and nitrogen use efficiencies, so that it can serve as a source of plant nutrients. Using wastewater in lieu of freshwater also can save up to 50% application of inorganic nitrogen fertilizer if the wastewater contains 40 mg N L^{-1}. Among the materials found in the wastewater, the nitrogen, phosphorus and potassium can be referred. Although, these elements are among essential elements required by a plant, in case of their excessive content in the soil, they will be associated with adverse effects such as unnecessary chlorophyll growth, delayed production, or discontinuation of reproductive development, and reduced product quality (Hassan

Oghli et al. 2005). The products that are often consumed raw are more sensitive and distinguished from those that are consumed after additional processing (wheat) or cooking (rice, potato) and non-food products(cotton, forage). Those products which are directly consumed by individuals, such as the vegetables and salads (root crops, lettuce etc.) in a raw form, require high-quality irrigation due to their pathogen content. Low-quality wastewater and water can be only used for the products that are processed before the consumption (Mohajeri and Horlemann 2017).

In Tadayon's (2008) study, the effect of sugar factory wastewater on aerial elements' content, yield, and yield components in two wheat cultivars was assessed during two years of cultivation. The outcomes of the study indicated that the lowest number of claws, scabs, and number of seeds in scabs, weight of one thousand seeds, and seed yield were obtained using wastewater treatment. Feyzi and Rezvani (2008) used Mashhad urban wastewater for the irrigation of barley, wheat, and triticale farms, and concluded that along with increasing wastewater amount up to 50%, the yield of all crops was enhanced. After two, five, and ten years of using wastewater in the farms in Jordan, Malhotra and Saxena (2002) concluded that barley plant's weight was increased, which underlines that the use of wastewater could respond plant's food requirement. Zare et al. (2017) investigated the effect of irrigation with treated wastewater on quantitative and qualitative characteristics of pinto beans. They used 0, 50, 75, and 100% treated wastewater and concluded that different wastewater ratios combined with freshwater are effective on growth traits and dry weight of plant's aerial organs. The average plant height and fresh and dry weights of crop aerial organs under full wastewater irrigation were 17.8, 22.5, and 18.1% higher than the control group, respectively. By increasing the amount of wastewater up to 100%, the nitrogen, phosphorus, and potassium adsorption rates increased by 100% compared to the normal water treatment, indicating a significant difference between the treatments.

Along with the irrigation with wastewater, the yield, yield components, and dry matter yield of the plants such as grass, cotton, wheat, barley, maize, forage sorghum, peas, sugar beet, rapeseed, green bean and red bean were significantly increased as well. Similarly, considering dianthus barbatus and snapdragon indicated an increase in their dry weight in the presence of wastewater and sewage sludge. Besides, applying wastewater irrigation led to reduced sugar content and increased gross sugar yield in sugar beet. Also, urban wastewater irrigation significantly increased the growth of olive trees. In an opposite manner, there was no significant difference between corn and sunflower irrigated with wastewater and well water in terms of yield and yield components (Yaghmaei 2000; Abedi Kopeai et al. 2003; Mostafazadeh et al. 2005; Ghanbari et al. 2007; Emami et al. 2007; Zolfaghari and Haghayeghi-Moghadam 2008; Saffari et al. 2008; Jalali et al. 2010; Hernandez et al. 1991; Oron et al. 1991; Dafonsca et al. 2007; Munir et al. 2007).

Arast et al. (2018) considered some corn and alfalfa farms irrigated with saline water, brackish water, wastewater, and integrated irrigation of wastewater and saline water. These farms underwent flood irrigation for nearly six months with the intended treatments. The studied wastewater contained significant amounts of nutritional elements required for the plant, which was beneficial for meeting the needs of crops in addition to provision of adequate water for plants' irrigation. By improving physical and fertility properties of the soil, wastewater treatment and integrated treatment of wastewater and saline water increased yield growth of cultivated plants in studied fields. The yield of tomato fruit in a full irrigation with wastewater was 47.8% greater than the control treatment using well water. The yields of lettuce and spinach increased along with increasing the wastewater level, which could be attributed to the presence of nitrogen and phosphorus content in the wastewater (Afyuni et al. 1997; Erfani et al. 2002). The Canola yield was evaluated in five irrigation treatments including100% wastewater (t1), 75% wastewater (t2), 50% wastewater (t3), 25% wastewater (t4), well water (t5), and well water with chemical fertilizer (t6) while the results of t1 showed the increased yield of this product (Fig. 6). The study conducted in Zabol city of Iran used five irrigation treatments including: using well water in all stages (t1),well water irrigation up to the flowering stage and then wastewater irrigation from the flowering stage up to the end of growth period (t2), well water irrigation to stem emergence stage and then wastewater irrigation from stem emergence to the end of growth period (t3), well water irrigation to tillering stage and thereafter, wastewater irrigation from tillering to the end of growth period (t4), and wastewater irrigation in all stages of plant growth (t5) and eventually represented the increased protein content in wheat seeds (Fig. 7) (Ghanbari et al. 2007).

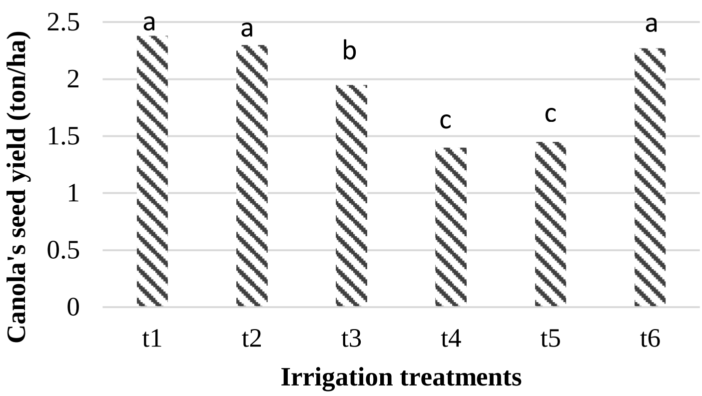

Fig. 6 The effect of different irrigation treatments on Canola's seed yield (Source: Zolfagari and Haghayeghi Moghadam 2008)

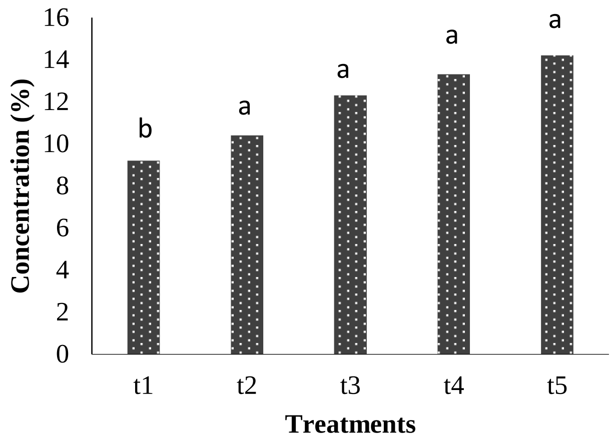

Fig. 7 The effect of different irrigation treatments on wheat seed protein content (Source: Ghanbari et al. 2007)

Wastewater irrigation increased the protein content of some plants such as grass, sorghum, corn, millet, and wheat (Ghanbari et al. 2007; Emami et al. 2007; Da fonseca et al. 2007). Sarvari et al. (2009) also proved that increasing wastewater brings about the enhancement in nitrogen and protein content and wheat seed yield. In their study, no significant difference was detected among the treatments in terms of 1000-seed weight, stem dry weight, aerial organ, dry weight and stem height at the end of vegetative growth. The use of wastewater in grass irrigation has been focused by several researchers. Earlier studies disclosed that wastewater has no effect on the color, density, and adsorption of nitrogen, iron, and zinc of the grass; nonetheless, higher amounts of phosphorus and potassium were observed in the grass. Moreover, irrigation with wastewater causes grass height increase (Abedi Kopaei et al. 2003; Emami et al. 2007; Malekian et al. 2008). Chorom and Aghaie Foroushani (2007) and Chorom and Ahmadzadeh Sarvestani (2010) proposed the use of sludge in the soil as an appropriate method for increasing plants' growth. Sou/Dakoure et al. (2013) showed that eggplant production was decreased in wastewater irrigated plot. Abegunrin et al. (2016) showed that Eggplant vegetables grew better under abattoir wastewater while the Spinach grew better under bathroom, laundry wastewater. Yassin et al. (2017) showed that total quantity, total plant biomass/treatment and weight of melon fruit increased in treated wastewater irrigated fields at Gaza strip.

Proper irrigation methods for wastewater application

In the absence of adequate water quality, the use of surface irrigation, due to direct contact with irrigation water, especially when protective clothing (eg boots, shoes and gloves) is not used, would be quite dangerous not only for district employees, but also for other people living in that area. It is notable that improper management can cause malaria, liver infections, filariasis, and onchocerciasis (Feyen and Badji 1993). Drip irrigation has been used in the Middle East for many years and has proved to be helpful not only for the water use efficiency and salinity control, but also for reducing the epidemic risks associated with wastewater reuse. Given the fact that salt has a radial movement at the irrigation point and is accumulated in the soil, it is necessary to improve wastewater quality in terms of suspended solids in order to prevent droplet system' obstruction (Mohajeri and Horlemann 2017). In this regard, a study was performed to compare the advantages and disadvantages of applying different irrigation methods while exploiting wastewater. The findings uncovered that drip irrigation is assumed as the only method which is capable of overcoming specific problems caused by wastewater usage (Pescod 1992). Also, the use of filtration in drip irrigation leads to reduced pollution indexes (Table 7). In addition, the use of surface drip irrigation (DI) and sub-surface drip irrigation (SDI) would be highly effective to control environmental contaminations in comparison with surface irrigation method. The reason is that in these methods, soil acts as a filter and because of that a smaller amount of biological contamination can enter the soil surface environment, which eliminates the concerns about the workers' direct contact with the surface soil (Najafi et al. 2006; Malekian et al. 2008; Oron 1999; Tabatabaei and Najafi 2009).

Table 7 Values of biological characteristics and the effect of drip irrigation filtration (Source: Najafi et al. 2006)

Characteristics	After filtration	Before filtration	Efficiency (%)
54	17	34	BOD_5(mg L^{-1})
98.5	9.3×10^4	6.8×10^6	Total bacteria (CFU. ml^{-1})
99	4.3×10^3	9.3×10^7	Total coliform (MPN. $100ml^{-1}$)
99	2.3×10^3	4.3×10^7	Fecal coliform (MPN. $100ml^{-1}$)
57.1	1.5	3.5	Egg parasite ($N.I^{-1}$)

Another study revealed that water drainage of a permeable tube in the case of wastewater application would be higher than well water, and such an increase is significant at the pressure of 0.4 atm and level of 5% (Abedi Kopaei et al. 2003). The use of wastewater in sub-surface irrigation would lead to yield increase in different plants compared to other irrigation methods. This irrigation method can be introduced as an effective approach of using wastewater in irrigation. This issue is illustrated for the grass in Fig. 8. In this figure, PW is subsurface wastewater irrigation, PG is subsurface well water irrigation, SW is surface wastewater irrigation, and SG is surface well water irrigation (Malekian et al. 2008; Rafiei Al-Hosseini et al. 2010; Oron et al. 1991).

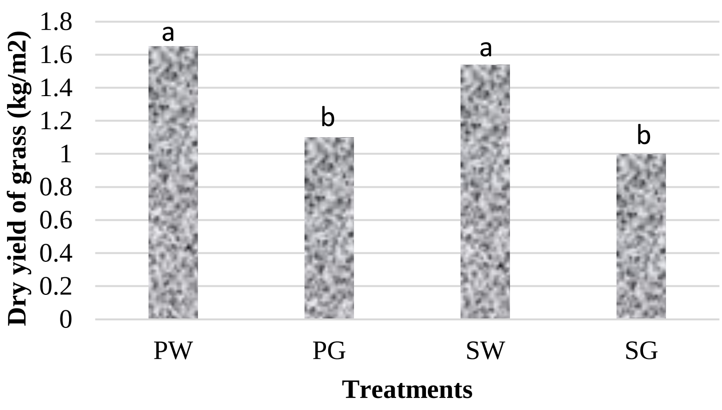

Fig. 8 Dry yield of grass under different irrigation methods with wastewater and well water (Source: Malekian et al. 2008)

Heidarpour et al. (2007) investigated the effects of wastewater on chemical properties of the soil using two irrigation methods (ground irrigation with porous pipes and surface irrigation) in Mahmoudabad Research Center of Isfahan, Iran. The soil samples were collected from the depths of 0-15, 15-30, and 30-60 cm. The amount of salt (EC), sodium (Na), calcium (Ca), magnesium (Mg), total nitrogen (TN), phosphorus (P), and potassium (K) was measured. The EC, Na, and Mg contents in the first layer of the soil (0-15 cm) with the use of ground irrigation were significantly higher than the surface irrigation. However, the EC, Ca, and Mg contents in the second and third layers of the soil irrigated with wastewater were less than the soil irrigated with groundwater. The content of K in the first and second layers of the soil irrigated with wastewater was significantly higher than the soil irrigated with the groundwater. Also, irrigation with wastewater had no significant effect on sodium, phosphorus, and total nitrogen (TN) of the soil. A study was conducted to evaluate the effect of three irrigation methods, using effluent versus freshwater, on water savings and irrigation water use efficiency (IWUE). Three main treatments consist of subsurface drip (SSD), surface drip (SD) and furrow irrigation (FI) and two sub-treatments effluent and freshwater were used. Wastewater treatment plant of Marvdasht city (Southern Iran) was used during 2005 and 2006. The highest yield (12.11 $\times 10^3$ kg ha^{-1}) was observed in SSD and the lowest was observed in the FI method (9.75 $\times 10^3$ kg ha^{-1}). The irrigation methods showed a highly significant difference in irrigation water use efficiency. The maximum IWUE was measured in the SSD (2.12 kg m−3) and the minimum was measured in the FI method (1.43 kg m−3). Irrigation with effluent led to a greater IWUE compared to freshwater, but the difference was not statistically significant (Hassanli et al. 2009).

Assadian et al. (2005) studied the effects of mixed wastewater, treated wastewater (secondary treatment), and filtered wastewater in sandy loam and clay loam soil under spinach farming with subsurface drip irrigation. After 30 days, the use of salt resulted in the system obstruction. The soil salinity (electrical conductivity) and sodium absorption were increased up to 3 dS/m and 7, respectively. Salt accumulation in the soil surface and clay soils was more observable than that in the sandy soils. The movement of the virus in sandy soils was limited to the total radius of 10 cm around the subsurface area while the preferred irrigation water flow toward clay soils' surface caused the virus to move toward the soil surface. Bacteriophages were observed in the seams and cracks of both soil types and remained up to 28 days after the irrigation. Nevertheless, the bacteriophage was not detected in the spinach leaves of any of the soils.

Martijn and Redwood (2005) stated that local irrigation methods such as surface and subsurface drip irrigation are appropriate method. Because these methods minimize pathogen dispersion to crops and workers. Also, these methods increase uptake of mobile nutrients by crops (Martijn and Huibers 2001). Balkhair (2016) investigated the effects of domestic wastewater quality on Radish crop and soil profile under surface and subsurface drip irrigation system at Jeddah, Saudi Arabia. Final results showed that yield increased and the count of bacteria decreased under subsurface irrigation system.

Economic advantages of wastewater reuse

Containing the nutrients, wastewater leads to plant growth increase as well as reduced need to chemical fertilizers, which consequently reduces the production costs. Irrigation with TWW has been applied in many countries: nutrients of TWW can replace fertilizers and soil amenders (Qadir et al. 2007) Supporting this claim, it was shown that the nutrient elements in the leaves of pine trees irrigated with well water were significantly less than the trees irrigated with wastewater (Table 8). The results of this study indicated that urban wastewater can be used for irrigation and as a fertilizer source in forest planting along with precise monitoring and control (Tabari et al. 2007). The use of urban wastewater in calcareous soils (which have a high buffering potential that can partially neutralize the absorption of heavy metals by plants) and in arid and semi-arid areas (with severe water shortages) could be helpful to enhance the yield of some specific crops (such as wheat that are not consumed raw) (Shahbazadeh and AmiriNejad 2018).

Table 8 Comparing the nutrient elements of pine leaves in two studied areas of Tehran (Source: Tabari et al. 2007)

Zn (gr/kg)	Fe (gr/kg)	K (gr/kg)	P (gr/kg)	N (%)	Minerals
30.62^a (5.99)	110.00^a (9.12)	8.12^a (1.05)	1.04^a (0.024)	3.07^a (0.098)	Irrigation with urban wastewater
20.62^b (2.60)	91.87^b (7.18)	5.73^b (0.73)	0.71^b(0.014)	2.68^b (0.203)	Irrigation with well water

*The numbers in the table represent the mean of iterations and the numbers in parentheses represent standard deviations

Being wealthy of nitrogen and phosphorus and other high and low consumption elements, wastewater has the potential to be used as an irrigation water source in the region in order to reduce the use of agricultural fertilizers (Table 9). In most of the plants irrigated with wastewater, the plant's yield has been significantly increased, which is economically of great importance (Mostafazadeh et al. 2005; Aghabarati 2006; Tabari et al. 2007; Moradmand 2008; Rafiei Al-Hosseini et al. 2010; Meli et al. 2002; Ramirez et al. 2002; Rattan et al. 2005).

Table 9 The comparison of the nutrients in well water and irrigation water (Source: Tabari et al. 2007)

Nutrients	Urban wastewater	Well water
NH4-N	9.05[a](0.11)	2.15[b](0.19)
NO3-N	1.63[a](0.09)	0.24[b](0.08)
PO4-P	12.69[a](0.167)	5.03[b](0.01)
K	39.93[a](0.83)	19.72[b](0.36)
Fe	6.33[a](0.12)	0.73[b](0.01)
Zn	3.30[a](0.06)	0.4[b](0.07)

Wastewater application effects on water resources' contamination

Wastewater irrigation with the sodium and salt levels typically higher than the groundwater results in increasing sodification rate of the shallow groundwater. Sugar beet and wheat crops in plains of Hamedan, Iran, are commonly irrigated with treated wastewater due to the lack of access to surface water and groundwater. Plant's wastewater contains salt and sodium compounds. The volume of wastewater and surface area of the regions irrigated by sewage are increasing over the time. Disposal of the wastewater containing significant amounts of Na^{+} ions is a serious threat for the soil salinization in these regions, which can negatively affect crops' long-term sustainability (Jalali et al. 2008). The rapid movement of water in Karstic areas causes groundwater pollution in these areas in semi-arid environments. Schmidt et al. (2013) investigated the quality of groundwater of the western margin of the Lower Jordan Valley. The area was populated and consequently chloride concentration of springs increases due to effluent infiltration. Choloride was applied as tracer. Recharge was between 25% and 50% of the precipitation. The springs exhibited a wastewater borne flow fraction between 0% and 20%. The successful application of these methods underlines the value of long-term monitoring, even at a comparatively low time resolution.

Nitrogen contamination is also another indicator of widespread pollution caused by human intervention in groundwater. This excessive nitrogen reaches the groundwater due to the extreme use of chemicals, and fertilizers in agricultural sector, disposal of animal waste, and also through the wastewater disposal systems (Joekar-Niasar and Ataie-Ashtiani 2009; Hajhamad and Almasri 2009). In order to reduce the risk of groundwater pollution, the use of fertilizer in agricultural farms should be limited, and the government should encourage farmers to use organic fertilizers. So, the produced internal wastewater should be efficiently treated prior to disposal (Barzegar et al. 2018). Nejatijahromi et al. (2019) determine the sources of nitrate pollution in groundwater of Varamin aquifer located southeast of Tehran, Iran. Their results showed that denitrification is a major transformation process occurring at the western and southwestern parts of the aquifer. Seasonal variations in the nitrogen and oxygen isotopic compositions of nitrate were more obvious in the wet season compared to the dry season. Their experiments also show that how concentration of nitrate is increased in the area where it was irrigated with wastewater. Jesmanitafti et al. (2014) investigated environmental effects of the use of industrial zones' sewage effluents on green spaces' irrigation. For this purpose, Shokohieh Industrial Park was selected as the study sample in Qom Province located at the center of Iran. The quality and quantity of inlet and outlet wastewater of the treatment plant were measured in the treatment plant laboratory of Shokoieh Industrial Park over 12 months from March 2012 to March 2013. Then, the analysis of chemical, biological, and physical indicators of wastewater irrigation (sewage) and heavy metals' measurement were performed according to standard instructions represented for water and wastewater treatment. According to the results, the main constraint of using Qom Industrial Park wastewater for green spaces' irrigation was the entry of chemical contaminants such as nitrates into the groundwater, soil salinization, and soil toxicity. Gallegos et al. (1999) studied the environmental effects of wastewater irrigation on groundwater in two locations of Mexico. High concentrations of fecal coliforms and total coliforms in both locations were recorded, and as a result, fecal bacteria transmission under the ground surface was reported. Likewise, the nitrate was found in all groundwater samples. Wastewater irrigation seemed to have negative effects on the groundwater quality. In order to overcome this problem, it is recommended to apply wastewater treatment before the irrigation parallel to precise management of the irrigation process. Viccaro et al. (2017) stated that with using the wastewater, nutrients and water are provided for crops which lead to increasing production rate (economic benefits) and reducing the use of fertilizer and well water (environment benefits).

Pharmaceuticals in Wastewater, a Growing Global Concern

Absorbable organically bound halogens, known as AOX compounds, which are used in some types of pharmaceuticals, are toxic to aquatic environments and the organisms living in them (Kummerer et al. 1998). The AOX compounds' concentrations in effluents of six different German hospitals have been measured about 0.13 – 0.94 mg/L (some of AOXs belong to other resources such as disinfectants used which can be ignored due to its low measures in comparison to pharmaceuticals) (Kummerer et al. 1998). The Iodine-131 (the most widely used radiopharmaceutical) concentration in sewage sludge from three water pollution control plant (WPCPs) on the Long Island of New York City has been measured about 0.027 ± 0.002 to 148 ± 4 Bq/g dry weight (Rose and Swanson 2013). Some pharmaceutical compounds' mean concentrations in effluents of two Wastewater treatment plant (WWTPs) and their receiving bodies in Po di Volano, Italy, have been reported to be higher than their Predicted no effect concentration (PNECs) (Al Aukidy et al. 2012). From Antibiotics (antibacterial drugs); Azithromycin (Mean: 175 – PNEC: 150 ng/L), Clarithromycin (Mean: 102, 283 – PNEC: 70 ng/L) and Sulfamethoxazole (Mean: 97, 91 – PNEC: 70 ng/L) can be mentioned. And from other medicines in the Po di Volano wastewaters can mention the anti-inflammatory drugs (Diclofenac, Ketoprofen, Mefenamic Acid), antidiabetics like Glibenclamide, antihypertensives like Hydrochlorothiazide and so others (Al Aukidy et al. 2012). A summary of the measured value is presented in Table 10.

In Tunisia, Neomycin and Kanamycin B have the highest wastewater concentrations among the antibiotic drugs (16.4 and 7.5 ng/ml, respectively) (Tahrani et al. 2016). The concentrations of some other antibiotic drugs, in river water system in Australia, such as Amoxicillin, Cefaclor, Penicillin G, Penicillin V, Cephalexin, Ciprofloxacin, Nalidixic Acid and so many others have been evaluated as 200, 200, 250, 10, 100, 1300 and 750 ng/L, respectively (Fatta-Kassinos et al. 2010). Considering the data mentioned, it can be concluded that the wastewater plants are almost inefficient and week in water pharmaceutical filtering and it is a leak which can lead to harmful environment and health damages, including antibiotic resistance (Kummerer 2004).

Table 10 A brief vision of pharmaceuticals' concentrations in water in some regions and countries around the world (Al Aukidy et al. 2012; MacLaren et al. 2018; Tahrani et al. 2016; Boyd et al. 2003)

Medicine Class	Name	Concentration (ng/L)	Location	PNEC* (ng/L)
Antibiotics	Azithromycin	44, 175	Italy, Italy	150
	Ciprofloxacin	25, 248	Italy, Italy	938000
	Clarithromycin	102, 283	Italy, Italy	70
	Chloramphenicol	3300	Tunisia	-
	Gentamycin c1a	1600, 500	Tunisia, Tunisia	-
	Gentamycin c2	1000	Tunisia	-
	Metronidazole	16, 19	Italy, Italy	2500
	Roxithromycin	12	Italy	4000
	Sisomycin	6700	Tunisia	-
	Sulfamethoxazole	97, 91	Italy, Italy	27
	Trimethoprim	27	Italy	2600
	Diclofenac	665, 339	Italy, Italy	
Analgesics/anti-inflammatories	Ketoprofen	23, 21	Italy, Italy	9700
	Mefenamic acid	26	Italy	15600
	Naproxen	21, 37, 107	Italy, Mississippi River, Lake Pontchartrain	428 2620
	Propyphenazone	33	Italy	
				800
Diuretics	Furosemide	14, 235	Italy, Italy	-
Antihypertensives	Hydrochlorothiazide	145, 385	Italy, Italy	-
Lipid regulators	Bezafibrate	3	Italy	-
Antidiabetics	Glibenclamide	36	Italy	-
	Metformin	1-47 µg/L (WWTP effluent) 0.06-3 µg/L (Surface water)	Worldwide Worldwide	-

*Predicted No Effect Concentration (PNEC)

Future outlooks and improvements of wastewater reuse

In addition to considering wastewater as agricultural water resources, the use of wastewater for irrigation has been widely expanded in recent years. The decision-making about the use of wastewater in agriculture depends on the kind of plant, soil texture, irrigation system and the periods of wastewater application. The use of the wastewater instead of the fresh water leads to the change of some of soil characteristics such as physical chemical properties. These changes depend on the soil type, time duration and the quality of the effluent. Several researchers reported hydrophobicity as one of the side-effects of long-term use of wastewater or sewage sludge application (Chen et al. 2003; Lerner 2003; Tarchitzky et al. 2007; Arye et al. 2011; Nourmahnad et al. 2015). Hydrophobicity reduces soil water infiltration and increases soil surface runoff. Using wastewater increases nitrogen, phosphorus and potassium, so that in most of the plants irrigated with wastewater, the plant's yield has been significantly increased, by improving physical and fertility properties. Some researches indicated increasing heavy metal in soil (Alghobar and Suresh 2015; Shahbazadeh and Amirinejad 2018) and some others show that no effects of wastewater on heavy metal accumulation in soil (Hussain and A1-Saati 1999; Kebonye et al. 2017). Increasing the heavy metals in the soil increases their content in the plant (Lente et al. 2014; Gupta et al. 2012). The use of some adsorbents such as rice husk and leaf compost can remove heavy metals (copper, nickel, zinc, and chromium) from industrial wastewater (Mohammadi et al. 2010).

Almost the effects of long-term irrigation with treated urban wastewater on the soil and crops were more considerable than the short- term irrigation. Khaliq et al. (2017) stated that groundwater and treated wastewater irrigation improve the soil characteristics, and also increase plants' growth and their yield. However, at least five years of irrigation are required to show the effects of composted sewage sludge on soil fertility and crop yield. Hence, recommendations and guidelines for the farmers can be formulated at least after five years after field experiments. Generally, coliforms' population at the soil layers depends on the soil texture, irrigation methods and varied from the cold to hot seasons. Mostly when the quality and type of the wastewater is appropriate, it can be used in agriculture. Albeit in order to reduce the risk of groundwater pollution, the produced internal wastewater should be efficiently treated prior to disposal (Barzegar et al. 2018).

Conclusion

In short, following conclusions can be inferred from the studies conducted on wastewater and its application:

- Wastewater and sewage sludge improve the physical properties of the soil such as soil permeability, porosity, formation of soil sponge structure, stability of soil aggregates, water holding (retention) capacity, hydraulic conductivity, and sometimes soil salinity reduction. In other words, the long -term use of wastewater increases hydraulic conductivity, permeability, porosity and also reduced bulk density. Though, some other studies have reported soil salinity increase as a result of wastewater application.
- Soils have a very important role in improving the quality of pollutants due to their specific physical, chemical and biological properties. In fact, the best way of treated wastewater disposal is to dispose it in the soil.
- Treated wastewater disposal in the soil, in addition to improving the soil properties, causes the plants to benefit from the nutrients which exist in the wastewater. This reduces the consumption rate of chemical fertilizers and eliminates some wastewater treatment processes, which is economically very appropriate.
- The studies in this field confirmed that drip irrigation, especially sub-surface drip irrigation, is the best way to utilize the wastewater; since, in this method, the soil acts as a filter and minimizes the contact between the soil, plant, and human being, and consequently less biological contamination would incur the surface soil.
- One of the major concerns in the field of using wastewater is the accumulation of heavy metals in the soil and plants, especially in a long term. Irrigating a particular plant with wastewater requires sufficient investigations of heavy metals' accumulation in that plant in order to control these elements' concentration in the plant and to prevent exceeding permitted standard levels.
- Three types of wastewater application for livestock forage, meadow, green space irrigation, artificial nutrition, and industry are considered in most cases as the best wastewater treatment options.

- Monitoring and wastewater treatment to remove harmful substances before applying for irrigation is an essential criterion to ensure environment protection and public health. In order to minimize negative irrigation effects with wastewater, it is crucial to develop strict instructions and an appropriate wastewater treatment system.
- The wastewater plants around the world are almost inefficient in the filtration of water pharmaceutical and there is a leak to the water resources which potentially causes the health damages, including antibiotic resistance. It is concluded that Pharmaceuticals presence in wastewater is a growing global concern.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study

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