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Effects of using wastewater on soil chemical properties under drip and furrow irrigation methods

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Abstract

The significance of water consumption within the economic, humanistic, agricultural, and industrial realms may not be ignored. Hence, the implementation of a variety of methods for irrigation through low-quality water such as wastewater is considered as an appropriate as well as a practical approach. In addition, wastewater can be regarded as a rich source with reference to mineral and organic substances leading to soil fertilization. In order to evaluate the wastewater effects, the present study aimed to investigate the refined municipal wastewater of Kerman (in Iran) on the chemical characteristics of soil within the framework of the two methods of drip and furrow irrigation in comparison to well-water irrigation. Also, the present study scrutinized a six-day irrigation period throughout six-month period. The samples were obtained from the middle part of atmosphere in the two depth parts of 0-30 cms and 30-60 cms in four treatments of furrow irrigation with well water, furrow irrigation with wastewater, drip irrigation with well water, as well as drip irrigation with wastewater within the framework of perfect randomized blocks through three frequencies. The results showed reduction in acidity amount, increase in salinity, increase in phosphorus phosphor, as well as increase in nitrate nitrogen and in the concentration of heavy metals in the depth of soils through furrow irrigation in comparison to drip irrigation.

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Introduction

The increasing growth of world's population has made the agricultural activities to be synchronized with it in order to increase supplying nutritional materials. Nevertheless, successive droughts in recent years have led the farmers living in dry lands to exploit fresh water resources to its utmost extent in the countries which possess dry lands. Hence, regarding the problem of fresh water shortage in the dry lands and arid areas, the utilization of wastewater can be considered as an alternative approach for irrigation. Also, it can be positively justified through economic as well as environmental issues. In addition, wastewater can be considered as a source rich in mineral and organic materials for fertilizing soil. A plethora of studies have demonstrated that the utilization of wastewater for irrigation enjoys a direct impact on the soil characteristics.

Thereby, the PH level of soil in the lands irrigated with wastewater is significantly lower than the lands irrigated with normal water. Many studies have reported the reduction of soil acidity in the conditions of wastewater irrigation because of the increase in organic materials, the formation of acid intermediate materials and gases such as H_2S (Mojiri, 2011). Moreover, the salinity level of soils irrigated with wastewater is higher than normal soils. The results of a number of studies, also, demonstrated an increase in the nitrogen, phosphor, as well as potassium levels in soil; however, the changes in the level of heavy metals have a direct correlation with the years of wastewater irrigation (8 and 11).

Carrying out their study on the impact of municipal wastewater of Ahvaz (in Iran) on soil hydraulic properties, Hanifloo and Moazed (2007) concluded a significant increase in the saturated hydraulic conductivity coefficient and permeability of the soil surface in comparison to irrigation with Karoon river (in Ahvaz) water. Furthermore, Heidarpour *et al.* (2007) investigated the influence of refined wastewater on the chemical properties of soil such as electrical conductivity, sodium, calcium, magnesium soluble, nitrogen, phosphorus and potassium, in both surface and subsurface irrigation. The results of the study showed that the utilization of subsurface irrigation causes an increase in electrical conductivity, sodium, and magnesium soluble within the surface level of soil.

Nevertheless, the changes in the parameters of soil texture, true density, porosity and water penetration are not reported to be significant. Besides, Rezapour *et al.* (2012) scrutinized the reaction of physical and chemical properties of soil after a long period of irrigation with wastewater in the semi-dry land. They concluded that the utilization of wastewater for irrigation causes the increase of 80 percent hydraulic conductivity, 350 percent of organic Carbon, 100 percent of Nitrogen, and 300 percent of Potassium. Another study carried out by Karimzadeh *et al.* (2012) indicated that the utilization of wastewater for irrigation causes the reduction of hydraulic conductivity of soil and the increase of soil weight.

Meli *et al.* (2002) investigated the influence of municipal wastewater on the chemical and microbiological properties of soil in the semi-dry lands. Their study implicated that the utilization of municipal wastewater causes the fertilization and productivity of soil. In another study, Aiello *et al.* (2007) investigated the impact of refined wastewater on soil properties through exploiting drip irrigation.

They concluded that the utilization of wastewater causes an increase in the pollution level of microbes as well as a reduction in the porosity and hydraulic conductivity in the soil surface. Furthermore, Zu *et al.* (2010) evaluated the long-term distance influence (i.e., 20 years) of refined wastewater on agricultural soils. They demonstrated that the utilization of wastewater results in the reduction of PH but a five-percent increase in the heavy metals within the surface.

In their study, Sacco *et al.* (2012) scrutinized the seasonal changes in the physical properties of soil under different conditions of irrigation for rice plants. In addition, Blum *et al.* (2012) investigated the changes in the soil properties of a cane farm after irrigation with refined wastewater within a two-year timeline. They concluded that such changes were significantly much more severe in the first year rather that the second year in terms of chemical properties. SauDakoure *et al.* (2013) assessed the irrigation impact of industrial wastewater on soil properties. They reported a disorganized soil structure and unsuitable soil physical conditions after irrigation with wastewater. Moreover, Papadopoulos *et al.* (2014) investigated the organic materials which positively influence the quality of soil physical properties.

Kerman province enjoys the average annual rainfall of 145 mm and evaporation of 1700 mm; also, this province which is located in Iran suffers from severe limitations in terms of water resources. One of asymmetrical water resources in Kerman is the municipal sewage-processing and wastewater refinery system which was established in 2007. Thereby, more than 20 thousand subscribers has exploited from its refined water. It has been predicted that this refinery system will be exploited to its utmost potential which is 38.5 million cubic meters annually until 2026 (Asdi *et al*, 2010).

Hence, considering the aforementioned issues, we can exploit from the municipal sewage-processing and wastewater refinery system, especially in dry and semi-dry lands. In addition, in case this refined wastewater is utilized for farmlands, one can pave the way for saving water, reducing the costs of supplying water, as well as minimizing soil fertilizer consumption. Also, the physical and chemical properties of soil irrigated with refined wastewater in Kerman can be considered as one of the innovations of the present study.

Meanwhile, no similar study with respect to physical and chemical analysis of the soil in this has been carried out. The present study aims to investigate the refined municipal wastewater of Kerman (in Iran) on the chemical characteristics of soil within the framework of the two methods of drip and furrow irrigation in comparison to well-water irrigation.

Materials and methods

Treatments Carried

In order to evaluate the effects of refined municipal wastewater of Kerman on the soil chemical properties within the framework of applying drip and furrow irrigation, the present study carried out an experiment on a research land of 16×10 meters located at a distance of 500 meters away from the municipal wastewater of Kerman within the framework of perfect randomized blocks through three frequencies without the condition of planting in 2012. In this experiment, the effects of four treatments (i.e., T1= furrow irrigation with well water; T2= furrow irrigation with wastewater; T3= drip irrigation with well water; T4= drip irrigation with wastewater) were compared within the same condition of farmland soil. The treatments were done in plots of width and length of four meters including four rows of barley stacks with the distance of 75 cms from each other. Also, two meters spaces of the experiments' frequencies were put vertically next to one another. Furthermore, the total numbers of plots including the frequencies were counted to be 12.

Method of Sampling and Measurement

The current study utilized 7000 cubic meters of water in a hectare through 30 frequencies of irrigation (irrigation circle of 6 days). In order to measure physical and chemical parameters of soil, the two depths of 0-30 cms and 30-60 cms were sampled. It should be noted that the aquifer pipes in drip irrigation system were positioned in the middle of barley. The measured parameters were reported to be:

Soil acidity amount (evaluated by an electronic PH-meter device), soil salinity (assessed by electronic conductivity measurement tool), Sodium absorption ratio (counted by a formula with reference to Sodium, Calcium, and magnesium level), phosphorus phosphor (measured by Spectrophotometer through using the method of Olsen), nitrate nitrogen (assessed by Kajdal measurement tool), organic Carbon (measured by the method of oxidation with dichromate), as well as concentrations of heavy metals such as nickel, cadmium, zinc, and iron (evaluated by atomic absorption spectrophotometer equipped with a graphite furnace according to the method described by APHA). In addition, the water flow rate to each plot was measured by volumetric flow. It should be noted that the data obtained were analyzed by MSTAT-C software and the means were compared using Duncan's test (at the 99% confidence level).

Results

Tables 1 and 2 show the analyses of some chemical properties of both well water and wastewater as well as soil physical properties, respectively. As can be seen in table 1, the refined municipal wastewater of Kerman (in Iran) is standardized with respect to the total parameters under investigation comparing the standards proposed by the Iranian Environmental Protection Agency (consumable in agriculture). Moreover, the soil physical properties of the area under study are shown in table 2. Also, the means comparison of some soil chemical properties regarding post-study results rather than the pre-study indicates that the soil acidity level is significantly reduced by wastewater (table 3).

Table 1. the chemical properties of well and waste water as well as the standardization of contamination border for agricultural purposes.

measured parameters	Well Water	Waste Water	Boundary pollution standards in agriculture[1]
pH	6.75	6.4	6/8.5
Ec (dS/m)	1.5	2.3	-
Na (meq/l)	3.6	14.3	-
Ca (meq/l)	1.4	3.2	-
Mg (meq/l)	2.1	2.7	4.1
SAR $(meq/l)^{0.5}$	2.7	8.4	-
P- phosphate (meq/l)	-	2.6	-
N- Nitrate (meq/l)	-	38.9	-
TOC (meq/l)	-	74.1	-
Co (meq/l)	-	0.014	0.05
Ni (meq/l)	-	0.087	2
Fe (meq/l)	-	0.029	3
Zn (meq/l)	-	0.002	2
BOD (ppm)	-	34	100
COD (ppm)	-	51	200

1- Iranian Environmental Protection Agency

Table 2. the analysis of some soil physical properties under study.

Depth measured (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density (gr/cm^3)	True density (gr/cm^3)
Before experiments					
0-30	57.5	28.2	14.3	1.42	2.67
30-60	51.3	31.9	16.8	1.37	2.71
0-60	54.4	30.1	15.5	1.39	2.69

Table 3. Comparison of the decomposition of some soil chemical properties.

Depth (cm)	pH	EC (dS/m)	Na (meq/l)	Ca (meq/l)	Mg (meq/l)	SAR $(meq/l)^{0.5}$	Cd (meq/l)	Ni (meq/l)	Fe (meq/l)	Zn (meq/l)
Before experiments										
0-30	7.1b	1.05d	3.14d	5.85a	3.51a	1.45d	0.0001c	0.0055d	0.0001b	0.0035c
30-60	7.4a	0.95e	2.71e	1.74c	3.22b	1.33d	0.0001c	0.0038e	0.0001b	0.0035c
0-60	7.2	1	2.92	5.29	3.36	1.39	0.0001	0.0046	0.0001	0.003
After experiments (in furrow and drip irrigation with well Water)										
0-30	6.9c	1.11d	3.45c	4.72c	3.11c	1.73c	0.0001c	0.0057d	0.0001b	0.0027c
30-60	7.1b	1.07d	3.42c	5.28a	3.09c	1.68c	0.0001c	0.0031e	0.0001b	0.0027c
0-60	7	1.09	3.43	5	3.1	1.7	0.0001	0.0044	0.0001	0.0027
After experiments (in drip irrigation with Waste Water)										
0-30	6.6d	1.81b	6.64b	4.31d	3.19b	3.42b	0.0025b	0.0089c	0.0007a	0.008b
30-60	6.68c	1.55c	6.21b	4.74c	3.07c	3.14b	0.0021b	0.0071c	0.00052a	0.007b
0-60	6.7	1.68	6.42	4.52	3.13	3.78	0.0023	0.008	0.00061	0.0075
After experiments (in furrow drip irrigation with Waste Water)										
0-30	6.1e	2.11a	8.58a	5.02b	3.25b	4.23a	0.0047ab	0.0142a	0.0012a	0.0127a
30-60	6.5d	1.84b	8.31a	4.97b	3.21b	4.11a	0.0032a	0.0109b	0.0009a	0.0109a
0-60	6.3	1.97	8.44	5	3.23	4.17	0.004	0.0125	0.00011	0.0608

Discussion and conclusions

The Analysis of Soil Acidity

As can be seen in table 3, the reduction of soil acidity level in the condition of utilizing wastewater in the furrow irrigation system is reported to be significant. Also, the soil acidity level in the depths of 0-60 cms in the condition of utilizing wastewater in the furrow irrigation system comparing the level of soil acidity before carrying out the current study is reduced by 12.5 percent. It is worth mentioning that the reduction of PH in soil in the condition of utilizing wastewater in the drip irrigation system comparing the level of soil acidity before carrying out the current study is reported to be 6.9 percent. A plethora of studies have linked the formation of intermediate acid materials and gases such as H_2S with the reduction of soil acidity level with regard to the condition of utilizing wastewater (Mojiri, 2011). In addition, the comparison of soil acidity means in the depths of soil (as can be seen in table 3) shows that the increase in the depth leads to higher soil acidity level. It seems that the reduction of soil PH in the soil surface rather that the soil depth may be related to the fact that the soil surface enjoys the condition of easier availability of air penetration to the soil leading to an increase in the rate of decomposition of organic materials such as nitrification process which reduces the acidity level of soil.

Analysis of Soil Salinity

As can be seen in table 3, the results comparison of soil chemical decomposition indicates that the utilization of wastewater for soil rather than well water with regard to drip and furrow irrigation in the depth of 0-60 cms increases soil salinity by 44.67 and 35.11 percent, respectively. Considering the salinity in wastewater under study which was reported to be twice more than the salinity in soil, one may expect that the increase in soil salinity after irrigation is due to wastewater utilization. A great number of researchers have demonstrated the increase in soil salinity due to the utilization of wastewater (Mojiri, 2011). Moreover, many researchers have found evidence of the link between the increase in EC of soil irrigated with wastewater and the high concentration of Cations such as Na within wastewater leading to the increase of EC (Kaschl *et al*, 2002). Table 3 shows the comparison of means with respect to soil salinity in the two depths and demonstrates that an increase in depth leads to the reduction of soil salinity level. In the condition of wastewater utilization for soil, the concentration of organic materials in soil surface is increased. Also, due to the lack of time for the decomposition of organic materials, the penetration of wastewater into the depth of soil is reduced; hence, adequate condition is provided for the concentration of salt within the soil surface. In this regard, McLaren *et al.* (2003) reported that the level of organic materials in the wastewater plays an important role in the penetration property of soil so that an increase in the amount of organic materials causes in blocking soil outlets and reducing the penetration of wastewater to the depth of soil.

Analysis of Sodium Absorption Ratio

As can be seen in table 3, the means comparison of Sodium absorption ratio within the depths under study and the condition of utilizing wastewater in terms of the two methods of irrigation indicated that the depth increase results in the reduction of Sodium absorption ratio. The reason of such reduction may lie in the concentration of solution Cations in the upper levels of soil surface rather than the deep layers of soil. In addition, as table 3 shows, irrigation with wastewater rather than irrigation with well water significantly increases Sodium absorption ratio. Wastewater enjoys a high amount of Sodium and disrupts the natural balance of the soil solution Cations resulting in the replacement of sodium with other Cations, particularly calcium and magnesium existing within the exchangeable levels of soil; therefore, Sodium absorption ratio is increased. Besides, the means comparison of utilizing wastewater in terms of furrow and drip irrigation in the Sodium absorption ratio demonstrates that Sodium absorption ratio with regard to the method of furrow irrigation is higher than the method of drip irrigation by 9.5 percent.

Analysis of P- phosphate

Phosphor is considered as one of the nutritional factors influencing the occurrence of eutrophication phenomenon which lowers the quality of water in case it is transmitted to surface as well as underground water. The present study measured the level of soil phosphor in terms of phosphate. Therefore, as can be seen in fig. 1, the means comparison of soil phosphate influenced by wastewater indicates that the level of soil phosphate is higher than the period before carrying out the study. Also, table 1 illustrates a significant increase in the level of soil phosphate in the condition of utilizing wastewater in the system of furrow irrigation (T4) so that the level of soil phosphate in the depth of 0-60 cms of soil in the condition of utilizing wastewater in the system of furrow irrigation is increased by 86.4 percent in comparison to the period before carrying out the study. Meanwhile, the level of soil phosphate in the condition of utilizing wastewater in the system of drip irrigation (T3) is increased by 68.7 percent in comparison to the period before carrying out the study. Considering the lower level of phosphor movement in soil, the concentration of phosphor in the surface levels of soil is considerable (Khai ey al, 2008). Hence, as can be seen in table 1, the present research investigated the means comparison of phosphate in the depths under study and demonstrated that an increase in depth results in a reduction in soil phosphate.

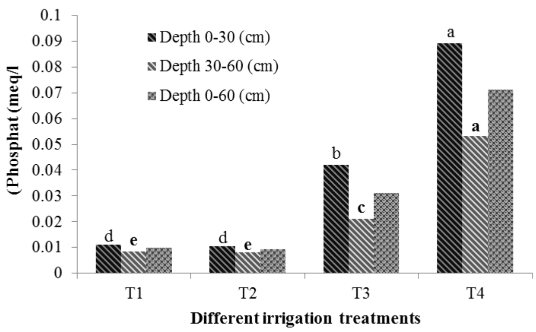

Fig. 1. Means comparison of Soil Phosphate Analysis.

Nitrate Nitrogen Analysis

As a result of applying wastewater to soil, a considerable amount of nitrogen is added to it. Such an amount depends on the Nitrogen level in wastewater and the volume of wastewater. One of the forms of Nitrogen is considered to be Nitrate Ion. Since nitrate ion is negatively charged, it has a high level of dynamism. In case it is not absorbed by plants or micro-organisms, it brings about health threats for human beings (Hosseinpour *et al*, 2008).

As can be shown in table 2, the means comparison of the decomposition of soil nitrate illustrates that the applying the treatment of wastewater, rather than well water, to farmlands with regard to the two systems of irrigation, namely furrow and drip, in the depth of 0-60 cms results in the increases of 86.1 and 79.9 percent of soil nitrate before carrying out the present study, respectively. Furthermore, as the depth increases, the soil nitrate level decreases. Since the accumulation of organic materials is higher in surface of soil profile, it is hypothesized that the high level if nitrate in the soil surface may be due to the decomposition of organic materials as well as the release of ammonium which leads to the increase of Anion in the soil surface as a result of nitrate phenomenon.

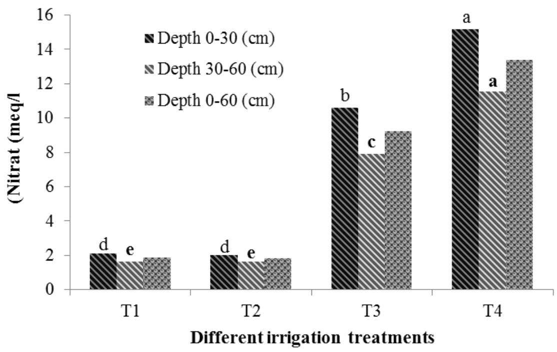

Fig. 2. the means comparison of soil nitrate decomposition.

The Analysis of Total Organic Carbon

The existence of soluble organic materials in soil indicates the presence of microbial compounds and resistant organic compounds for the process decomposition. Resistant organic compounds enjoy the property of environmental accumulation for decomposition which are poisonous for soil micro-organisms as well as plants. Also, such compounds bring about carcinogenic effects for human beings. Considering the many advantages of organic materials, the existence of total organic Carbon in soil soluble results in the dynamicity of heavy metals in the depth of soil and brings about changes in the oxidation potential of soil. In addition, preferential binding of soluble organic compounds with calcium and magnesium leads to increased dispersion of soil particles. The means comparison of total organic Carbon in the depth of soil under the influence of applying wastewater through the two methods of irrigation (as can be seen in fig. 3) illustrates that an increase in depth results in the reduction of total organic Carbon.

The results of the current research is in line with McLaren *et al.*'s (2003) study which reported that an increase in the depth of soil causes the reduction of total organic Carbon. Organic Carbon is considered as the most important parameter quality and enhancement of soil fertilization (Sepaskhah & Kariz, 2011). Hence, the results of the current study demonstrate that irrigation with wastewater results in higher level of total organic Carbon than irrigation with well water. In the same line of research, Najafi and Nasr (2009) reported that when the treatment soils were applied municipal wastewater, the organic Carbon increased significantly in comparison to the treatment and control soils with chemical fertilizers.

Their study, also, showed that the level of total organic Carbon in the treatment soil with municipal wastewater enjoyed a 41-percent increase in comparison to both treatment and control soils. Moreover, the comparison of applying wastewater with regard to the two methods of drip and furrow irrigations on the total organic Carbon in soil indicates that the total organic Carbon with reference to the method of furrow irrigation in the depth of 0-60 cms is higher than its counterpart irrigation, namely drip, by 25.9 percent increase.

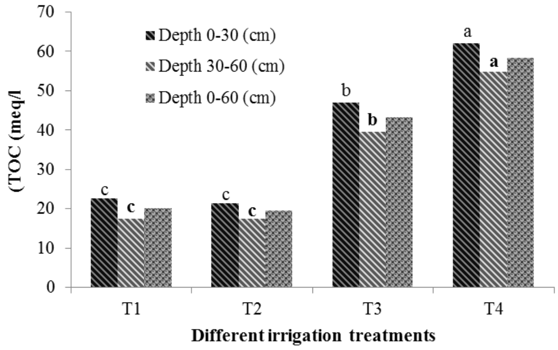

Fig. 3: the means comparison of total organic Carbon decomposition

The Analysis of Heavy Elements

Heavy elements enjoy high levels of consumption in terms of urban, service-related, agricultural, as well as industrial activities. Also, in case water is consumed, these heavy elements may find their way into sewage. Heavy metals have adverse effects on the quality of agricultural products, soil fertility, and underground water in the environment (Hosseinpour *et al.* 2008). On the one hand, different soil properties, its composition, and its degree of wastewater treatment and irrigation methods play an important role in the transmission of heavy metals into groundwater. On the other, one may not expect a significant increase in the concentration of metals in only one year since the concentration level of these elements in wastewater is meager. The concentration of heavy elements in soil during irrigation with wastewater depends upon a number of factors such as the elements' concentration in wastewater, the period of wastewater irrigation, soil structure, acidity, as well as the percentage of soil organic materials. The means comparison of heavy elements in the depths of soil under study was influenced by applying wastewater through the two methods of irrigation (as illustrated in table 3). In other words, an increase in soil depth reduced the amount of heavy elements. Furthermore, Hosseinpour *et al.* (2008) concluded that the amount of heavy elements is higher in the lower depths of soil rather than the surface level of soil. Nevertheless, in the present study, the transmission of heavy elements into the depth of 30-60 cms of soil shows that the structural type of soil can be considered as one of the influential factors in increasing the percentage of heavy elements transmission toward the lower depths of soil. Moreover, the movement rate of heavy metals within the soils with large poles results in the transmission of heavy elements which are attached to these particles since some parts of colloidal sediments and clay particles along with the movement of soil soluble lead to such transmission. Besides, the transmission of total organic Carbon and the process of increasing its movement percentage into the lower depths of soil through time can be regarded as other significant factors. In another study, Kaschel *et al.* (2002) reported that the amount of heavy metals within the soils with alkaline acidity significantly increases due to their bonding with soluble organic materials.

Conclusions

The results of the current study demonstrated that refined wastewater significantly influences the chemical properties of soil within the framework of applying two methods of drip and furrow irrigation. The study, also, concluded that the refined wastewater system of Kerman province (in Iran) in comparison to fresh water impacted on the reduction of soil acidity level; however, it influenced on the increase of salinity, sodium absorption ratio, phosphate, nitrate, as well as total organic carbon with respect to soil structural level. In addition, the investigation of the effect of municipal refined wastewater in the two depths of 0-30 cms and 30-60 cms demonstrated that in case the depth level of soil is increased, its acidity level is significantly increased as well. Nonetheless, the soil levels of salinity, sodium absorption ratio, phosphate, nitrate, as well as total organic carbon are considerably reduced in comparison to the soil surface. The current study utilized the two methods of methods, namely drip and furrow, and the consumed volume of water was 7000 cubic meters in a hectare. The results showed the chemical properties of soil were significantly increased with respect to furrow irrigation rather than its counterpart method termed as drip irrigation. Hence, considering the fresh water shortage in the dry lands and arid areas, the utilization of wastewater as an alternative approach can not only play a significant role in environmental issues, but also it can pave the way for justifying economic problems. Last but not least, applying drip irrigation systems in the gardens and farmlands of Kerman province is increasingly developing; therefore, its water source can be shifted toward the more economical wastewater municipal resource rather than fresh or well water.

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