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Research Article

Quality Proficiency to Crop, Soil and Irrigation System of Recycled Wastewater from the Van/Edremit Wastewater Treatment Plant

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Abstract: Increasing pressure on water resources in the world has revealed the necessity of using marginal water resources in irrigation. With the use of wastewater, which is one of the marginal water resources, the pressure on freshwater resources is alleviated, the discharge problems of wastewater are solved, and soil and crop productivity increase with the high nutritive effect of wastewater. However, salinity, heavy metals, some harmful chemicals, and the pathogen risks of wastewater should not be ignored. In this context, in this study, the effluent of the wastewater treatment plant located in the central Edremit district of Van province was evaluated in terms of usability in irrigation. Samples were taken from treated wastewater during the vegetation period in 2020 and 2021 and pH, EC, cation and anions, micro elements and heavy metal, total nitrogen and phosphorus, total suspended solids, chemical oxygen demand, biological oxygen demand, fecal coliform, percent sodium, sodium adsorption rate, residual sodium carbonate and Langelier saturation index were determined by analysis and calculations. As a result of the study, the treated wastewater does not pose a risk in terms of pH, EC, cation and anions, micro elements and heavy metal, total suspended solids, percent sodium, sodium adsorption rate, residual sodium carbonate, langelier saturation index and fecal coliform, but attention should be paid to the total nitrogen and phosphorus, chemical and biological oxygen demand contents. It was concluded that the treated wastewater is in compliance with national and international standards, and there is no harm in its use in irrigation and thus treated wastewater can be recommended as a reliable water source for irrigation in the semi-arid province of Van/Edremit. However, in order to ensure safe and sustainable management in irrigation with wastewater, it is necessary to monitor water quality and make necessary inspections of soil, crop and irrigation systems.

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Footnote: This study includes a part of the doctoral thesis prepared by the first author.

1. Introduction

The increasing pressure on water resources in the world has revealed the necessity of using marginal water resources in the agricultural sector, which is the largest consumer of fresh water. Treated wastewater, which is one of the marginal water resources (Çakmakcı et al., 2016), can be defined as water that has been polluted as a result of different uses and whose properties have changed completely or slightly. Although the content of typical wastewater varies depending on the source and time, approximately 99% is water and the remainder is composed of colloidal and dissolved solid particles (UN, 2014).

Treated wastewater is a source of water and nutrients that can be used all year round, regardless of seasonality. Irrigation with treated wastewater provides higher yield, especially in arid and semi-arid regions, and also provides the opportunity to grow crops with high economic value (Qadir et al., 2015). Wastewaters are separated from other waters due to their rich organic matter, nitrogen, phosphorus, and potassium contents, and with these aspects, they increase soil and crop productivity with their use in irrigation (Becerra-Castro et al., 2015; Rivas et al., 2017; Yerli et al., 2022). In addition, considering the heavy metal and pathogen risks in the use of wastewater in irrigation, it is of great importance to carry out irrigations (Dogan Demir and Sahin, 2017; Demir, 2021). In a study, it was stated that untreated wastewater contains more macro and micro elements than a chemical fertilizer (Qin and Horvath, 2020). When irrigating 1000 m^3 per hectare with domestic wastewater, an average of 16 to 62 kg of nitrogen, 4 to 24 kg of phosphorus, and 2 to 96 kg of potassium can be added to the soil (Qadir et al., 2007). With the use of treated wastewater in irrigation, the need for synthetic fertilizers decreases, and this contributes to economic production by reducing the chemical fertilizer input as well as the environmental impact. In a study, it was reported that in conditions where wastewater is used in irrigation, approximately 135 dollars per hectare is saved in fertilizer costs (Jimenez et al., 2010). Treated wastewater, which acts as a natural fertilizer with its high organic and inorganic substance contents, improves and develops the soil structure and provides an increase in yield and quality in crop production. In addition, with the use of treated wastewater in irrigation, environmental contributions are provided, and the discharge problems of wastewater are solved.

Wastewaters can meet 30 to 70% of the irrigation water demand according to different regions (Raschid-Sally and Jayakody, 2009). It is known that 20 million hectares of agricultural land in the world are irrigated with wastewater (Koc et al., 2022). Winpenny et al. (2010) reported that approximately 10% of the irrigated agricultural lands around the world are irrigated with wastewater, and a total of 20 million hectares of agricultural land in 50 countries is irrigated with wastewater. Globally, wastewater use in agricultural lands accounts for approximately 11% of all irrigated agricultural land (Thebo et al., 2017). In addition to the insufficient data on the use of wastewater in irrigation in Türkiye, not much progress has been made. However, WHO (2006) stated that the reuse of wastewater would become the most important issue in Türkiye. The annual amount of treated wastewater in Türkiye is approximately 4.2 billion m^3 (TSI, 2018), which is an indicator of an important potential in terms of meeting the irrigation needs of agricultural lands in Türkiye.

Although the use of wastewater in irrigation brings high yield and quality, the risks they create should not be ignored. Wastewaters contain dissolved salts, heavy metals, and some other harmful chemicals and pathogens apart from nutrients (Dogan Demir and Sahin, 2019; Cakmakci and Sahin, 2021). This situation can reveal many negativities in soil quality, crop production, and live health. The sustainability of irrigation with wastewater can only be achieved by managing the effects of the crop, soil, irrigation system, and live health in irrigation with wastewater. In this context, in the use of recycled wastewater in irrigation, water quality must be evaluated, electrical conductivity and heavy metal content must be monitored, and pathogen and chemical risks must be followed. Dogan Demir and Sahin (2017) stated that the heavy metal content of tomato crops irrigated with wastewater increased. Similarly, Demir (2021) stated that heavy metal accumulation in the soil increased under wastewater irrigation conditions, and heavy metal accumulation in the soil should be monitored in irrigation with wastewater.

The following measures can be taken to reduce the risk of salinity caused by irrigation with wastewater; highly resistant to soil salinity; washing the salt from the soil, diluting the salinity in the active root zone by allowing salts to be transported outside the wet front using drip irrigation method; not sowing on the furrow ridge, which may be affected by salinity in seed sowing; ensuring that osmotic pressure remains at low levels by keeping soil moisture close to field capacity with frequent irrigation intervals; reducing the effect of salinity by irrigation cycles with wastewater and freshwater or irrigation by diluting wastewater with fresh water.

Precautions can be taken against the risk of Na accumulation, such as using treated wastewater only on soils with a sandy texture, adding organic matter to the soil (Pagliai et al., 2004), or adding a Ca source to the soil or irrigation water in use in clay soils against the risk of deterioration of the structure. (Hopkins et al., 2007). If there is a precipitated Ca source in the soil, Ca should be dissolved by reducing the pH value of the water in a controlled manner, taking into account the heavy metal mobility (Kanber and Unlu, 2010). Controlled nitrogen fertilizer or humic acid supplementation can be provided to promote leafing in crops against heavy metal risks and toxicity effects (Ding et al., 2019). In order to reduce the risks of pathogens and some harmful chemicals originating from wastewater, drip irrigation methods should be preferred instead of surface and sprinkler irrigation methods, and wastewater should not be preferred for irrigation of raw consumed crops. Filtration, dilute acid, and chlorine treatments are among the main measures to be taken, respectively, against possible physical, chemical, and biological cloggings in irrigation systems, especially drip irrigation, originating from wastewater (Sahin et al., 2005; Eroglu et al., 2009; Eroglu et al., 2012; Dandie et al., 2020; Hashem et al., 2021; Qiu et al., 2022).

According to the "Communique on Technical Procedures for Wastewater Treatment Plants" published in the Official Newspaper No. 27527 on 20.03.2010 in Türkiye, in the evaluation of the use of wastewater in irrigation, the amount of total solids and dissolved substances, electrical conductivity, sodium amount and the ratio of sodium to other cations, boron, heavy metals, and other toxic substances, organic matter load and the amount of floating substances such as oil and grease, pathogens and in some cases the total amount of calcium and magnesium should be examined (Anonymous, 2010). Although Türkiye has not come a long way regarding the use of wastewater in irrigation, studies on this subject are also very limited. In addition, in the literature review, no study was found in which the water quality of a treatment plant for the use of treated wastewater for irrigation was evaluated. In this context, in this study, the evaluation of the effluent of the wastewater treatment plant located in the central Edremit district of Van province in terms of usability in irrigation was determined according to the regulations in Türkiye and other international criteria. In addition, the measures that can be taken against possible problems are also mentioned.

2. Material and Methods

The recycled wastewater was taken from the biological wastewater treatment plant (38°24’53" N and 43°14’09" E) with a daily capacity of 10 400 m^3, located in the central Edremit district of Van province, which started operating in 2013. The inlet water of the treatment plant contains only domestic pollution elements of approximately 130 000 population and does not contain industrial and industrial wastes since there are no large-scale industrial facilities in the region. After entering the facility, the wastewater carried by the sewage line passes through the sand trap, coarse and fine screen, and is transferred to the pre-sedimentation pool and the aeration pool, respectively. After being aerated, the wastewater passing through the bacteria pool is transferred to the final settling unit and then discharged into the Lake Van. There are no farmers in the Van region who use wastewater for irrigation, and also the region has not made much progress in this regard.

The majority of the soils of Edremit district of Van province (38°42’28" N and 43°24’26" E) consist of alluvial soils with high $CaCO_3$ content, rich organic matter, mineral content, and medium textured (Turna and Eski, 2016). During the active crop production period (May-September) the precipitation amount is 92.2 mm, and the average temperature is 18.5°C (Anonymous, 2021). In the region consisting of approximately 124 000 decares of land, 101 000 decares of land are used as agricultural land, and more than half of this area is irrigated (Anonymous, 2022). The fruit trees and vegetable cultivation such as apples, pears, apricots, plums, walnuts, tomatoes, peppers, cucumbers, beans, cabbage, lettuce, and also alfalfa and silage corn production as forage crops and field crops are cultivated in the central Edremit district of Van province (Turna and Eski, 2016; Anonymous, 2022).

The samples were collected from treated wastewater in 3 periods (July, August, and September) in the vegetation period of 2020 and in 2 periods (July and August) in the vegetation period of 2021. Water samples were taken from the discharge point of the treatment plant. Then pH, electrical conductivity (EC), cations (Ca, Mg, Na, and K) and anions (CO_3, HCO_3, SO_4 , Cl and NO_3), micro elements and heavy metal contents (B, Fe, Cu, Mn, Zn, Pb, Cd, Cr, and Ni), total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD_5), fecal coliform, percent sodium (Na%), sodium adsorption rate (SAR), residual sodium carbonate (RSC) and Langelier saturation index (LSI) values were determined by analysis and calculations.

pH and EC are directly measured by pH and EC meter (Ayyildiz, 1983). Cations, micro elements and heavy metals; after being prepared for analysis with chemicals, measuring in an ICP-OES (Anonymous, 2007). CO_3 and HCO_3; using phenolphthalein and bromocrocel green indicators (Tuzuner, 1990). TP, SO_4, NO_3 and B; in Hach Lange Dr 5000 UV/VIS spectrophotometer, phosphor reagent no. HACH 8048 (Powder Pillow), SulfaVer 4 no. HACH 8051, Cadmium Reduction-HR no. HACH 8039, HACH 8015 Carmine methods with the help of ready kits (HACH, 2010). TN; Kjeldahl nitrogen determination method (APHA-AWWA-WEF, 1989). Cl; by titration with silver nitrate using potassium chromate indicator (Tuzuner, 1990). TSS; The residue left by the filtered water samples was dried at 105°C and weighed (APHA, 1995). COD; in HACH LCI 400 COD cuvette test with the help of Hach Lange Dr 5000 UV/VIS spectrophotometer and HACH LT 200 thermoreactor using Merck ready-made test kits (HACH, 2005). BOD_5; before the estimated BOD_5 value was obtained by performing COD analysis and the sample volumes determined according to this value were obtained by putting them in the Hach Lange Dr 5000 UV/VIS for 5 days and keeping them in the absorption incubator for 5 days (HACH, 2010). Fecal coliform; after the water sample was passed through the membrane filtration device, it was determined by analysis as the most probable number (MPN) (APHA, 1995).

The Na%, SAR, and RSC values were calculated according to Kanber and Unlu (2010) by considering the ion concentrations with the help of equations 1, 2, and 3, respectively. In order to determine whether lime sediment will occur in drippers due to irrigation, the LSI value was obtained with the help of equation 4 according to Ayers and Westcot (1994). In this equation, pH_a refers to the measured pH value, and pH_c refers to the theoretical pH value when the water reaches equilibrium with lime. This value was determined from ion concentrations according to Kanber and Unlu (2010).

$$Na\% = \frac{Na}{Na + Mg + Ca + K}\ x\ 100 \quad (1)$$

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

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \quad (3)$$

$$LSI = pH_a - pH_c \quad (4)$$

The quality of treated wastewater was evaluated according to the quality criteria according to the classes of inland water resources (Anonim, 2008) and irrigation water quality evaluation criteria (Anonim, 2010) and heavy metal contents of treated wastewater were evaluated according to permissible heavy metal amounts in irrigation water (Anonymous, 2010) and the water quality criteria affecting the clogging in the drip irrigation system were evaluated according to the water quality in the evaluation of the clogging in the drip irrigation method (Anonymous, 2010) and also some practical measures that could be taken were mentioned.

3. Results and Discussions

The result of pH, electrical conductivity (EC), cations (Ca, Mg, Na, and K), anions (CO_3, HCO_3, SO_4 , Cl, and NO_3), micro elements, and heavy metal contents (B, Fe, Cu, Mn, Zn, Pb, Cd, Cr, and Ni), total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), chemical oxygen demand (COD), biological oxygen demand (BOD_5), fecal coliform, percent sodium (Na%), sodium adsorption rate (SAR), residual sodium carbonate (RSC) and langelier saturation index (LSI) values of the recycled wastewater based on different periods and years are given in Table 1.

In terms of soil quality, the pH of irrigation water should be between 6.5 and 8.4 (Ayers and Westcot, 1994). While EC values of < 0.7 dS m^{-1} in irrigation waters do not pose a problem for crop nutrition and for the crop to benefit from soil water, a value between 0.7 and 3.0 dS m^{-1} may cause the problem to begin, and a value > 3.0 dS m^{-1} may cause the problem to be intensified (Kanber and Unlu, 2010). According to the US Salinity Laboratory System, treated wastewater is classified as C3 (high salt water for irrigation) (0.75 - 2.25 dS m^{-1}). Wastewater is classified as a no problem or low problem category in terms of pH, EC, infiltration, ion toxicity, and other effects (Ayers and Westcot, 1994). The pH values of the wastewater are included in the I. class water category according to the “Water Pollution Control Regulation” inland water resources classification (Anonymous, 2008). The EC values of the wastewater were evaluated in the category of water with little-moderate damage in use (II. class) according to the “Communique on Technical Procedures for WasteWater Treatment Plants” (Anonymous, 2010). In this case, the wastewater can be easily used for irrigation of crops with medium and high salinity resistance and for light and medium textured soils (Kanber and Unlu, 2010). The fruit trees and vegetable cultivation such as apples, pears, apricots, plums, walnuts, tomatoes, peppers, cucumbers, beans, cabbage, lettuce, and also alfalfa and silage corn production as forage crops and field crops are common in the region (Anonymous, 2022) and this considering that these crops show medium and high resistance to salinity, there will be no risky situation related to salinity in the use of treated wastewater in irrigation. In addition, considering that 65% of the region's soils have a loamy texture (Karaca et al., 2019), the risk of salinity in the use of treated wastewater in irrigation will decrease. However, in the use of treated wastewater in clay textured soils or crops sensitive to salinity, it can be specified as the precautions to be taken for the preservation of soil quality and for a reasonable crop production, performing irrigation with drip irrigation, reducing osmotic pressure by keeping soil moisture close to field capacity in root zone and carrying out washings by following the soil EC in certain periods.

Table 1. Quality analysis results of recycled wastewater

Parameter	July		August		September
	2020	2021	2020	2021	2020
pH	7.49	7.65	7.45	7.79	7.37
EC (dS m^{-1})	1.131	1.143	1.009	1.135	1.184
Ca (me l^{-1})	2.17	2.42	2.05	2.57	2.19
Mg (me l^{-1})	2.98	3.21	3.13	2.78	3.21
Na (me l^{-1})	4.11	4.09	4.19	4.25	4.02
K (me l^{-1})	0.92	1.25	1.01	1.36	0.95
CO_3 (me l^{-1})	-	-	-	-	-
HCO_3 (me l^{-1})	4.91	5.11	5.05	5.24	5.21
Cl (me l^{-1})	1.94	1.84	2.11	2.13	2.07
SO_4 (me l^{-1})	1.68	1.35	1.74	1.67	1.81
NO_3 (me l^{-1})	1.54	1.45	1.67	1.68	1.52
B (mg l^{-1})	0.51	0.42	0.59	0.49	0.56
Fe (mg l^{-1})	0.397	0.425	0.429	0.412	0.411
Cu (mg l^{-1})	0.011	0.011	0.012	0.010	0.010
Mn (mg l^{-1})	0.081	0.099	0.072	0.091	0.061
Zn (mg l^{-1})	0.015	0.015	0.015	0.015	0.016
Pb (mg l^{-1})	0.001	0.002	0.001	0.001	0.002
Cd (mg l^{-1})	0.002	-	0.002	-	-
Cr (mg l^{-1})	-	-	0.001	0.001	0.001
Ni (mg l^{-1})	0.036	0.045	0.038	0.049	0.041
TN (mg l^{-1})	12.65	10.35	9.93	11.27	10.27
TP (mg l^{-1})	1.51	1.15	1.87	1.21	1.69
TSS (mg l^{-1})	19.3	31.2	21.8	28.5	24.5
COD (mg l^{-1})	36.5	41.9	35.2	35.5	37.1
BOD_5 (mg l^{-1})	22.4	25.8	21.1	22.8	22.6
SAR	2.56	2.43	2.60	2.59	2.45
RSC (me l^{-1})	-0.24	-0.52	-0.13	-0.11	-0.19
Na%	40.4	37.3	40.4	38.8	38.8
LSI	0.324	0.599	0.299	0.664	0.247
Fecal coliform (MPN 100 ml^{-1})	145	167	121	149	139

‘‘-’’: Not detected.

When the values of Na, which has a high toxic effect, are examined, according to the "Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010), wastewater II. class belongs to the group. Thus, the level of damage to be caused by the use of wastewater in irrigation is considered as low-moderate. In addition, Na% and SAR values are calculated in order to determine the negative effect of Na on the soil structure (Pacci et al., 2022). Considering the

Na% and SAR values of the wastewater, it is seen that it is within the usable limits for irrigation (Kanber and Unlu, 2010). Another parameter evaluating the negative impact on soils is RSC. The RSC value in waters should be lower than 2.5 me l^{-1} (Kanber and Unlu, 2010). All RSC values in wastewater are negative and show that it does not pose a risk.

Wastewater is in the class of water that does not pose any risk in irrigation in terms of SO_4 content. Considering the quality criteria according to inland water resources classification (Anonymous, 2008), the wastewater is evaluated in the category of I. class waters in terms of SO_4. SO_4 content in irrigation waters is lower than 4 me l^{-1} in Scofield-1936 classification shows that the irrigation water class is very good, and there will be no problem with its use in irrigation (Kanber and Unlu, 2010). High concentration of HCO_3 causes Ca to precipitate and Na to become dominant, increasing Na damage (Kanber and Unlu, 2010). Ayers and Westcot (1994) reported that severe problems would occur if the HCO_3 content was > 8.5 me l^{-1}. In order to reduce the risk of Ca precipitate, it may be recommended to reduce the pH of the treated wastewater and thus to perform irrigations or to add Ca to the soil to prevent Na from becoming dominant. In addition, organic matter additives can also be effective. However, high organic matter (BOD_5) entry into the soil with treated wastewater will also reduce the negative effect of Na (Kanber and Unlu, 2010). The high organic matter contribution of the treated wastewater used in the study also eliminates this situation. Considering the toxicity effect of Na, the N supplied to the soil with the treated wastewater will reduce the negative effect of Na by promoting the growth and leafing of the crop (Ibrahim et al., 2018). Singh et al. (2016) reported that the negative effect of Na on the crop improved with the addition of N. However, in this study, the HCO_3 content was found below the limit values.

Cl ion, which has a high amount of toxic effect, is in the category of I. class waters that do not cause any problems in irrigation according to the “Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010). In addition, in terms of Cl ion, the wastewater was evaluated in I. class waters in Scofield-1936 (< 4 me l^{-1}), Doneen-1954 (< 5 me l^{-1}) and Christiansen-1977 (< 3 me l^{-1}) classifications (Kanber and Unlu, 2010). However, considering the "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008) in terms of Cl content, wastewater in the II. category of quality. According to the same regulation, wastewater in terms of NO_3 content is classified as IV. water quality. In this context, the pollution load of NO_3 should be monitored, and it would be beneficial to use the drip irrigation method with high efficiency in order to prevent leakage into groundwater in the use of treated wastewater in irrigation.

B is an essential element for crop growth in low amounts but is a special ion that has high toxicity in even low amounts (Yerli et al., 2020). When the concentrations of B in wastewater are examined, it has been evaluated in the class of water that does not pose any inconvenience to use, according to the "Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010). According to FAO (Ayers and Westcot, 1994) and the US Environmental Protection Agency (EPA, 2004), the amount of B in irrigation waters lower than 0.75 mg l^{-1} does not pose a problem in even long-term irrigation. However, attention should be paid to the sensitivity of the crop irrigated with wastewater to B toxicity. Stone fruits are more easily damaged by B than pome fruits (Kanber and Unlu, 2010). Considering that the resistance to B toxicity of apples, pears, apricots, plums, walnuts, cucumbers, and beans grown in the region is sensitive or semi-sensitive, precautions should be taken against B toxicity in irrigation with treated wastewater. In this context, the growth and leafing of the crop should be encouraged by supplementing with N from the outside, and its resistance to stress should be increased (Ding et al., 2019). However, since N already obtained from wastewater can provide this benefit, there is no need to give N from outside.

The Mn, Cu, Fe, Zn, Cr, Cd, Ni, and Pb contents of treated wastewater are below the maximum allowable values permitted by the "Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010) and the US Environmental Protection Agency (EPA, 2004). In addition, according to the "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008), treated wastewater does not pose a risk in its use in irrigation since it is in the class of water of good quality. However, in the long-term use of wastewater in the same region, possible accumulations in the soil and crops should be followed up. In addition, since some crops such as corn cultivated in the region absorb heavy metal more and accumulate it in their bodies (Ab Rhaman et al., 2021), it may be recommended to irrigate these crops with wastewater by diluting them with fresh water instead of directly treated wastewater. In long-term irrigation with wastewater, heavy metal risks can be reduced by using phytoremediation techniques with accumulator crops (Bhargava et al., 2012; Sharma et al., 2018).

N and P contained in wastewater have a positive effect on soil and crop growth. TN and TP contents of treated wastewater are listed as the lowest grade IV. category of class waters in the "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008). When the Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) of the wastewater are examined, according to the "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008), COD and BOD_5 are evaluated in the II. and IV. water categories, respectively. The excess of BOD_5 is considered as the input of dissolved organic matter into the soil. This improves the structure of the soil. Especially for agricultural lands where crop production is widespread and soil structure is deteriorated, the structure of the soil will be improved with the use of treated wastewater and it will become an alternative water source (Barbera et al., 2013; Çakmakcı and Sahin, 2019;2020).

Fecal coliforms contained in wastewater are the main source of many diseases in terms of health as a microbiological parameter. In general, its amount in water is expressed as the most probable number in 100 ml (MPN 100 ml^{-1}). According to the fecal coliform values of the treated wastewater, the quality of the wastewater is classified as II. class and is considered as water that has no objection to use in "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008). In addition, the limit values (1000 EMS 100 ml^{-1}) determined by the US Environmental Protection Agency (EPA, 2004) show that it will not cause any problems in using it in irrigation. However, in order to reduce possible risks, it may be recommended to prefer drip irrigation instead of surface and sprinkler irrigation methods in irrigation with treated wastewater and not to use treated wastewater for irrigation of raw consumed crops.

Although crops need cations in terms of development and growth, especially in conditions where the pH is > 8.0 in water, also the sum of Ca and Mg content is > 3, causing clogging in the irrigation system (Kanber and Unlu, 2010). Considering that the pH values of the wastewater are below 8 and the salinity values are < 2000 mg l^{-1}, the risk of clogging in the irrigation system has decreased. Another factor affecting clogging in the drip irrigation system is the amount of total suspended solids. According to the "Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010), the upper limit of the amount of total suspended solids that can be used in the drip irrigation system is 50 mg l^{-1}, thus reducing the risk of clogging in the use of wastewater in irrigation. According to the water quality criteria affecting the clogging in the drip irrigation system in the same communique, the wastewater was also included in the category of waters in which the risk of clogging is low or low-moderate in terms of Mn and Fe. In addition, the LSI values of the wastewater are positive and close to zero in the study indicating that there will be no risk in terms of lime accumulation. Dilute acid treatments are one of the precautions to be taken against possible clogging risks. Although strong acids prevent lime accumulation in drippers by lowering the pH of the water, crop nutrients may have an antagonistic or synergistic effect with each other depending on the decreasing pH. In addition, organic acids are also used in lime (Sahin et al., 2005; Eroglu et al., 2009; Eroglu et al., 2012; Dandie et al., 2020; Hashem et al., 2021; Qiu et al., 2022).

Conclusion

According to the analyzes of the wastewater evaluated during the irrigation seasons, it was seen that there were similarities in terms of quality criteria in both years of the study (2020 and 2021) and values close to each other were obtained. As a result of the evaluation of wastewater according to the "Water Pollution Control Regulation" inland water resources classification (Anonymous, 2008), "Communique on Technical Procedures for Wastewater Treatment Plants" (Anonymous, 2010), and other international criteria, it was concluded that there is generally no harm in its use in irrigation. In this context, treated wastewater was found to be recommendable as a reliable water source for agricultural irrigation in the Van/Edremit region. However, in regions where wastewater is irrigated for a long time, a quality control by matching the results obtained by keeping records by making follow ups in soil, crop, and drip irrigation systems with the quality parameters of treated wastewater will be important in terms of ensuring sustainability and environmental safety in wastewater irrigated agriculture in the region.

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References

Ab Rhaman, S. M. S., Naher, L., & Siddiquee, S. (2021). Mushroom quality related with various substrates' bioaccumulation and translocation of heavy metals. *Journal of Fungi, 8 (1)*, 42. doi: 10.3390/jof8010042.

Anonymous, (2007). *Microwave assisted acid digestion of sediments, sludges, soils, and oils*. https:/www.epa.gov/sites/production/files2015-12/documents/3051a.pdf Access date: 05.05.2018.

Anonymous, (2008). *Regulation amending the water pollution control regulation*. http://www.resmigazete.gov.tr/eskiler/2008/02/20080213-13.htm Access date: 03.04.2021.

Anonymous, (2010). *Communique on technical procedures for wastewater treatment plants.* https://www.resmigazete.gov.tr/eskiler/2010/03/20100320-7.htm Access date: 03.04.2021.

Anonymous, (2021). *Ministry of Agriculture and Forestry, General Directorate of Meteorology*. https://www.mgm.gov.tr/veridegerlenen/il-ve-ilcelerstatistic.aspx?m=VAN Access date: 15.09.2021.

Anonymous, (2022). *Edremit district report*. https://www.vantso.org.tr/u/files/5EDREMIT-GDPAOAQ_998.pdf Access date: 01.07.2022.

APHA, (1995). *Standard methods for examination of water and wastewater.* https://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf Access date: 17.10.2018.

APHA-AWWA-WPCF, (1989). *Standart methods for examination of water and wastewater*. https://www.techstreet.com/standards/standard-methods-for-the-examination-of-water-and-wastewater-23rdedition?gclid= EAIaIQobChMI8cO8 p8K24AIVFojVCh3qvwxIEAAYASAAEgLc_vD_BwE&sid=goog&product_id=1974889 Access date: 18.09.2018.

Ayers, R. S., & Westcot, D.W. (1994). *Water Quality for Agriculture-FAO Irrigation and Drainage Paper No: 29*, Food and Agriculture Organisation of United Nations, Roma.

Ayyildiz, M. (1983). *Irrigation Water Quality and Salinity Problems*. Ankara University Faculty of Agriculture Publications, Ankara.

Barbera, A. C., Maucieri, C., Cavallaro, V., Ioppolo, A., & Spagna, G. (2013). Effects of spreading olive mill wastewater on soil properties and crops, a review. *Agricultural Water Management, 119*, 43-53. doi: 10.1016/j.agwat.2012.12.009

Becerra-Castro, C., Lopes, A. R., Vaz-Moreira, I., Sılva, E. F., Manaia, C. M., & Nunes, O. C. (2015). Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environment International, 75*, 117-135. doi:10.1016/j.envint.2014.11.001

Bhargava, A., Carmona, F. F., Bhargava, M., & Srivastava, S. (2012). Approaches for enhanced phytoextraction of heavy metals. *Journal of Environmental Management, 105*, 103-120. doi: 10.1016/j.jenvman.2012.04.002

Cakmakci, T., & Sahin, U. (2021). Improving silage maize productivity using recycled wastewater under different irrigation methods. *Agr. Water Man., 255*, 107051. doi: 10.1016/j.agwat.2021.107051

Çakmakcı, T., Uçar, Y., & Erbaş, S. (2016). The effect of wastewater applications on oil content and compositions of canola (Brassica napus L.). *Yuzuncu Yıl University Journal of agricultural Sciences*, *26*(2), 145-151.

Çakmakcı, T., & Sahin, U. (2019). Evaluation of treated wastewater quality in terms of irrigation water within the framework of related legislation: the case of Van province. *Mustafa Kemal University Journal of Agricultural Sciences*, *24*, 249-256.

Çakmakcı, T., & Şahin, Ü. (2020). The wffect of using treated wastewater with different irrigation methods on silage maize macro-micro element and heavy metal accumulation. *Journal of Tekirdag Agricultural Faculty*, *17*(1), 12-23. https://doi.org/10.33462/jotaf.589446

Dandie, C. E., Ogunniyi, A. D., Ferro, S., Hall, B., Drigo, B., Chow, C. W., Venter, H., Myers, B., Deo, P., Donner, E., & Lombi, E. (2020). Disinfection options for irrigation water: Reducing the risk of fresh produce contamination with human pathogens. *Critical Reviews in Environmental Science and Technology, 50(20)*, 2144-2174. doi: 10.1080/10643389.2019.1704172.

Demir, Y. (2021). The effects of the applications of zeolite and biochar to the soils irrigated with treated wastewater on the heavy metal concentrations of the soils and leaching waters from the soils. (2021). *Carpathian J. of Earth and Env. Sci., 16 (1)*, 223-236. doi: 10.26471/cjees/2021/016/169

Ding, T., Lin, K., Yang, B., Yang, M., & Li, J. (2019). Toxic effects and metabolic fate of carbamazepine in diatom Navicula sp. as influenced by humic acid and nitrogen species. *Journal of Hazardous Materials, 378*, 120763. doi: 10.1016/j.jhazmat.2019.120763

Dogan Demir, A., & Sahin, U. (2017). Effects of different irrigation practices using treated wastewater on tomato yields, quality, water productivity, and soil and fruit mineral contents. *Environmental Science and Pollution Research, 24 (32)*, 24856-24879. doi: 10.1007/s11356-017-0139-3

Dogan Demir, A., & Sahin, U. (2019). Effects of recycled wastewater applications with different irrigation practices on the chemical properties of a vertisol. *Environmental Engineering Science 37 (2),* 10.1089/ees.2019.0156.

EPA, (2004). *Guidelines For Water Reuse*. United States Environmental Protection Agency, Washington, USA.

Eroglu, S., Sahin, F., Sahin, U., & Anapalı, O. (2009). Bacterial application for treatment of clogged emitters in drip irrigation systems as an environmentally friendly method. *New Biotechnology, 25,* S271-S272. doi: 10.1016/j.nbt.2009.06.611

Eroglu, S., Sahin, U., Tunc, T., & Sahin, F. (2012). Bacterial application increased the flow rate of $CaCO_3$-clogged emitters of drip irrigation system. *Journal of Environmental Management, 98*, 37-42. doi: 10.1016/j.jenvman.2011.12.014

HACH, (2005). *DR 5000 spectrometer procedures manuel.* http://tr.hach.com/quick. Searchdownloadsearch.jsa?keywords=kullan%C4%B1 Access date: 17.10.2018.

HACH, (2010). *Hach bodtrak II.* http://tr.hach.com/bod-trak-ii-aksesuarlar-ile-birlikte-respirometrikboi-aparat/productdownloadsd Access date: 17.10.2018.

Hashem, M. S., & Qi, X. (2021). Treated wastewater irrigation-A review. *Water, 13* (11), 1527. doi: 10.3390/w13111527.

Hopkins, B. G., Horneck, D. A., Stevens, R. G., Ellsworth, J. W., & Sullivan, D. M. (2007). Managing irrigation water quality for crop production in the Pacific Northwest. https://ir.library.oregonstate.edu/concern/administrative_report_or_publications/w3763710v Access date: 01.06.2021.

Ibrahim, M. E. H., Zhu, X., Zhou, G., Ali, A. A., Ahmad, I., & Farah, G. A. (2018). Nitrogen fertilizer alleviated negative impacts of NaCl on some physiological parameters of wheat. *Pakistan Journal of Botany, 50 (6)*, 2097-2104.

Jimenez, B., Drechsel, P., Kone, D., Bahri, A., Raschid-Sally, L., & Qadir, M. (2010). Wastewater, Sludge and Excreta Use in Developing Countries: an Overview. In P. Drechsel, C. A. Scott, L. Raschid-sally, M. Redwood & A. Bahri (Eds.), *Wastewater irrigation and health: assessing and mitigating risk in low-income countries*, (pp. 1-27). Earthscan, London, United Kingdom,

Kanber, R., & Unlu, M. (2010). *Water and Soil Salinity in Agriculture.* Çukurova University Faculty of Agriculture Publications, Adana.

Karaca, S., Sargin, B., & Turkmen, F. (2019). Investigation of some land and soil properties by geographical information system analysis: Van Province land and soil properties. *Turkish Journal of Agricultural Research, 6 (2),* 199-205. doi: 10.19159/tutad.542543

Koc, D. L., Can, M. E., & Kapur, B. (2022). Current Research in Agriculture, Forestry and Aquaculture. In T. Akar, I. Dasdemir & I. Cengizler (Eds.), *Use of Wastewaters and Saline Waters in Agriculture* (pp. 108-125). Gece Publishing House.

Pagliai, M., Vignozzi, N., & Pellegrini, S. (2004). Soil structure and the effect of management practices. *Soil and Tillage Research, 79 (2),* 131-143. doi: 10.1016/j.still.2004.07.002

Pacci, S., Dengiz, O., Saygın, F., & Alaboz, P. (2022). Soil Quality Assessment of Paddy Cultivation Lands in the Bafra Plain Based on the SMAF Model. Turkish Journal of Agricultural Research, *9*(2), 164-174.

Qadir, M., Mateo-Sagasta, J., Jimenez, B., Siebe, C., Siemens, J., & Hanjra, M. A. (2015). Environmental Risks and Cost-Effective Risk Management in Wastewater Usesystems. In P. Drechsel, M. Qadir, D. Wichelns (Eds.), *Wastewater: economicasset in an urbanizing world*, (pp. 55-72). Springer, London.

Qadir, M., Wichelns, D., Raschid-Sally, L., Minhas, P. S., Drechsel, P., Bahri, A., Mccornick, P. G., Abaidoo, R., Attia, F., & Elguındy, S. (2007). Agricultural Use of Marginal-Quality Water: Opportunities and Challenges. In D. Moden (Ed.), *Water management in agriculture,* (pp. 425-457). Earthscan, London and International Water Management Institute, Colombo.

Qin, Y., & Horvath, A. (2020). Use of alternative water sources in irrigation: potential scales, costs, and environmental impacts in California. *Environmental Research Communications, 2 (5),* 055003. doi:10.1088/2515-7620/ab915e

Qiu, X., Wang, J., Wang, H., Wang, C., Sun, Y., & Li, G. (2022). Elimination of clogging of a biogas slurry drip irrigation system using the optimal acid and chlorine addition mode. *Agriculture, 12 (6)*, 777. doi: 10.3390/agriculture12060777.

Raschid-Sally, L., & Jayakody, P. (2009). *Drivers and Characteristics of Wastewater Agriculture in Developing Countries: Results from a Global Assessment*, IWMI.

Rivas, R. M. F., de Leon, G. S., Leal, J. A. R., Ramirez, J. M., & Romero, F. M. (2017). Characterization of dissolved organic matter in an agricultural wastewater-irrigated soil, in semi arid Mexico. *Revista Internacional de Contaminación Ambiental, 33 (4),* 575-590. doi: 10.20937/rica.2017.33.04.03

Sahin, U., Anapali, O., Donmez, M. F., & Sahin, F. (2005). Biological treatment of clogged emitters in a drip irrigation system. *Journal of Environmental Management, 76 (4)*, 338-341. doi: 10.1016/j.jenvman.2005.02.003

Sharma, S., Nagpal, A. K., & Kaur, I. (2018). Heavy metal contamination in soil, food crops and associated health risks for residents of Ropar wetland, Punjab, India and its environs. *Food Chemistry, 255*, 15-22. doi: 10.1016/j.foodchem.2018.02.037

Singh, M., Singh, V. P., & Prasad, S. M. (2016). Nitrogen modifies NaCl toxicity in eggplant seedlings: Assessment of chlorophyll a fluorescence, antioxidative response and proline metabolism. *Biocatalysis and Agricultural Biotechnology, 7,* 76-86. doi: 10.1016/j.bcab.2016.05.007

Thebo, A. L., Drechsel, P., Lambin, E., & Nelson, K. A. (2017). Global, spatially-explicit assessment of irrigated croplands influenced by urban wastewater flows. *Environmental Research Letters, 12*, 074008. doi: 10.1088/1748-9329/aa75d1

TSI, (2018). Environment and Energy Statistics. Turkish Statistical Institute. https://tuikweb.tuik.gov.tr/PreHaberBultenleri .do?id=30667 Access date: 17.05.2021.

Turna, M., & Eski, H. (2016). Edremit district analysis, Eastern Anatolia Development Agency. https://www.kalkinmakutuphanesi.gov.tr/assets/upload/dosyalar/edremit.pdf Access date: 01.07.2022.

Tuzuner, A. (1990). *Soil and Water Analysis Laboratories Handbook*. T.R. Ministry of Agriculture, Forestry and Rural Affairs, General Directorate of Rural Services, Ankara.

UN, (2014). *The United Nations World Water Development Report 2014*. Water and Energy, Paris, France.

WHO, (2006). *Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume II: Wastewater Use in Agriculture*, World Health Organization, France.

Winpenny, J. T., Heinz, I., & Koo-Oshima, S. (2010). *The Wealth of Waste: The Economics of Wastewater Use in Agriculture*. Food and Agriculture Organization of The United Nations, Roma, Italy.

Yerli, C., Cakmakci, T., Sahin, U., & Tufenkci, S. (2020). The effects of heavy metals on soil, plant, water and human health. Turkish Journal of Nature and Science, 9 (Special Issue), 103-114. doi: 10.46810/tdfd.718449.

Yerli, C., Sahin, U., & Oztas, T. (2022). CO_2 emission from soil in silage maize irrigated with wastewater under deficit irrigation in direct sowing practice. *Agricultural Water Management, 271*, 107791. doi: 10.1016/j.agwat.2022.107791.