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Spatial Distribution of Hydro-Chemical Parameters and Trace Elements in Groundwater of Oued Souhil Area, Irrigated with Treated Wastewater (Tunisia)

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ABSTRACT

The area of Oued Souhil, located in north of Tunisia, is irrigated with treated wastewater (TWW) for over 40 years. The objectives of this study were to investigate the state of the hydro-chemical characteristics and the heavy metals content and their spatial variability. Water samples from two locations (A: downstream of Oued Souhil perimeter; B: out of Oued Souhil perimeter) have been collected September 2022, which correspond to the post-irrigation period. Water samples were analyzed for major ions (Na, K, Ca and Mg) as well as the trace elements (Cu, Zn, Fe and Mn). Overall, the water from both sampling locations is characterized by abundance of Na ions reaching 673 and 582 ppm in A and B, respectively. In contrast, Ca and K registered higher amounts in groundwater from location A with 77 and 150%, respectively. In addition, the spatial distribution of Ca, Mg and Na was similar. Thus, the mineral content of the groundwater is controlled by two factors: treated wastewater irrigation and seawater intrusion. Data revealed that trace element (Cu, Zn, Fe, Mn) concentrations did not exceed Tunisian standards. The spatial distribution of these elements was different.

Keywords: *Treated wastewater, Groundwater, Hydrochemistry, Trace elements, Tunisia.*

INTRODUCTION

In response to the increase of socio-economic development, urbanization and climate change, and water demand increases (FAO, 2012). Within the next 50 years, more than 40% of the world's population will face water stress or scarcity (WHO, 2006). The reuse of treated wastewater (TWW) has become a common approach and a practical solution, to attend the water scarcity issue and increase in turn the food production.

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According to estimations from 2017, approximately 35.9 Mha of irrigated croplands depend on urban wastewater flows globally (Hamilton et al., 2007). Reuse of treated wastewater in agriculture can be beneficial to the environment. Nevertheless, this practice can lead to threats such as the bioaccumulation and bio-magnification of metals and organic pollutants in crops, shifts in the physicochemical properties of soils, contamination of groundwater resources, and health hazards, among others (Ashraf et al., 2021; & Hashem & Qi, 2021).

The analysis of these effects is subject of many recent studies on the impacts of irrigation with TWW on salinity, heavy metals, and pathogenic microorganisms in groundwater. Studies from different countries examine how treated wastewater affects groundwater. Wang et al. (2008) and Li et al. (2007) evaluated the consequences of wastewater irrigation on groundwater in China and suggested various solutions to address the negative outcomes. In Tunisia, Dahmouni et al. (2019) studied the impact of reusing TWW on groundwater pollution. They highlighted that the content of Cobalt (Co), Chromium (Cr), Manganese (Mn), and Iron (Fe) exceeds the limits in the groundwater.

In this paper, we will analyze the effects of the use of TWW on groundwater quality. The goals were to (1) investigate the hydro-chemical characteristics of the groundwater; (2 interpret the spatial distribution of trace elements in the groundwater. The final purpose is to analyze the contamination of the groundwater and to assess the environmental risk.

MATERIALS AND METHODS

Study area

The study area covers a total surface of 240 ha. It is located in the suburbs of Nabeul city, there is an expansion of irrigated areas with treated wastewater: Oued Souhil. The Oued Souhil water table is part of the large coastal aquifer system of Nabeul-Hammamet which extends covering an area of approximately 100 km2. This aquifer is characterised by a thin reservoir rock varying from 1 to 3 m. For more than forty years, it was overexploited, leading to the intrusion of seawater along the coastal zone. The inventory of water points showed that the Nabeul-Hammamet water table is exploited by 3930 surface wells exploiting approximately 15 106 m3 compared with renewable water resources of around 12.5 106 m^3 (Chaieb, 2009). Since 2 September 1941, this water table has been a prohibited area. The water table, renowned for the chemical quality of its water, has been suffering since the 1970s from falling water levels and seawater intrusion, high levels of salinity reaching 4 to 6 g/l in places; this had a detrimental effect on the survival of citrus trees in the area.

The wastewater is of urban origin and comes from three agglomerations: Nabeul, Dar Chaabane and Beni Khiar. Then, it is treated at the SE4 and SE3 wastewater treatment plants before being discharged into the sea. Reuse of TWW was the only alternative to mitigate the problem of water scarcity, given that some of the treated effluent is used to irrigate citrus trees during the summer season. TWW used for irrigation is characterized by an average basic pH value of 7.7, and its EC reaches 4 dS/m, it presented also high amounts of Ca, Mg and K, reaching, respectively, 30, 25 and 41.5 mg/l (INRGREF, 2022).

The climate is semi-arid with mild winters and hot summers. The summer lasts typically from June to September. During winter, minimum temperatures are recorded between December and March. Average rainfall is around 400 mm/year. The area is characterized by a wet season from September to May and a dry season from June to August. The soil texture at Oued Souhil perimeter was sandy with a degraded structure (INRGREF, 2022).

Sampling procedure and analytical methods

One sampling campaign was carried out in September 2022. The sampling took place directly after irrigation with TWW at the beginning of the rainy season. A network of 18 wells was followed on the study site (A). Moreover, 3 wells were sampled out of Oued Souhil area (B). Water samples were collected from each well. Groundwater samples were sampled in bottles, pre-rinsed at least three times with groundwater to avoid contamination during sampling. After collection, samples were filtered then the following parameters were measured: Sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and trace elements like Fe, Cu, Mn and Zn were measured using atomic absorption spectrometry according to standard methods AFNOR N° NF FD T90-112 (1998). All concentrations are given in milligrams per liter (mg/l).

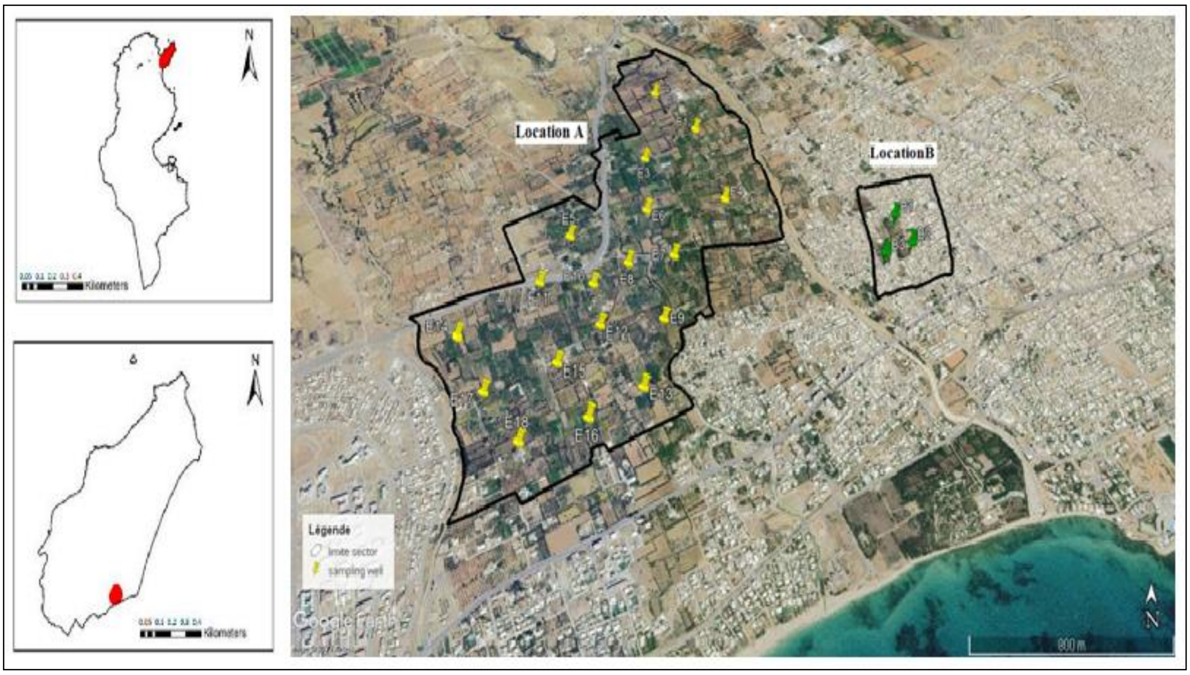

Figure 1: Location of the study area with monitoring wells

Statistical analysis

All statistical analyses were performed using the SPSS software. They included calculation of basic descriptive statistics as well as selected statistical tests. Spatial variability of elements concentration in groundwater was performed using the Surfer software.

RESULTS AND DISCUSSION

Hydro-chemical parameters

First, the chemical characteristics were analyzed. In Table 1, we summarized the groundwater quality downstream (A) and out (B) of the Oued Souhil perimeter. In both locations, the dominant cation is Na with values between 673 and 582 ppm in A and B, respectively. K and Ca ranged from 16 to 40 ppm and from 179 to 318 ppm in B and A locations, respectively, whereas Mg ranged from 84 to 99 in A and B locations, respectively. Overall, Na has the highest abundance, followed by Ca, Mg, and K has the lowest mean value in both locations (A and B). More interestingly, for Ca and K concentrations, data revealed a significant difference between groundwater in A and B. In contrast, for Na and Mg, no differences were observed. Because the Ca and K concentrations in treated wastewater are high, its use as irrigation water in Oued Souhil perimeter results in the increase of Ca and K in groundwater in location A. Similar results were found by Dahmouni et al. (2019) in Cebela-Borj-Touil, Tunis, observing a noticeable increase of ions in groundwater after irrigation of soils with treated wastewater. Furthermore, the elevated Na concentration in groundwater of both locations (A and B) demonstrated that groundwater sodification is not a result of using treated wastewater in irrigation, but it is due to seawater intrusion. The process of marine intrusion is accompanied by other processes that modify the hydrochemistry of water contaminated by marine water. The most remarkable process is the reverse cation exchange that takes place between the clays and the groundwater. This exchange consists of the release of Ca and the adsorption of Na (kouzana et al., 2007).

By analyzing data, the results revealed the abundance of trace elements Fe > Cu > Mn > Zn for the two locations (A and B). Moreover, no significant difference was revealed between the two locations. This result confirmed that TWW irrigation has not a negative impact on groundwater contamination by metals. Because positive metal ions have a strong affinity to the negative hydroxyl groups of organic matter and clays, the metals contained in wastewater may accumulate in topsoil and subsoil horizons of wastewater-irrigated areas (El Benna et al., 2013). Hence, some investigations have reported that TWW does not lead to groundwater pollution by metals (Yin et al., 2016). Conversely, current works have demonstrated that elements such as As, Cd, Cr, and Pb can migrate to deep soils in areas subjected to long-term TWW, reaching and contaminating shallow aquifers (El Benna et al., 2013; & Yang et al., 2021).

Despite that various metals can migrate through the soil profile, their infiltration into the aquifers may be influenced by several variables, including soil chemistry, soil particle size, low unsaturated zone thickness values (water-table levels generally lower than 8 m), and the hydro-geological structure of aquifers, among others (Yang et al., 2021; Dahmouni et al., 2019; & Yadav et al., 2015). Additionally, some wastewater characteristics such as pH, salinity, and the content of metals and dissolved organic matter may limit/promote the transport of metals to the saturated zone. In fact, some studies report metal contamination (As, Cd, Co, Cr, Cu, Ni, Pb, and Zn) in groundwater affected by TWW, whereby the concentrations of the above-mentioned elements exceed the permissible limits established in national standards and international guidelines for agricultural and/or drinking purposes (Dahmouni et al., 2019; & Lesser-Carillo et al., 2011).

Table 1: Groundwater hydrochemistry data in A and B locations

Location	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)
A	673,75	40,66	318,41	84,29	0,19	0,04	0,34	0,08
B	582,30	16,66	179,00	99,48	0,19	0,01	0,36	0,09
Significance	ns	*	*	ns	ns	ns	ns	ns

Spatial distribution

The spatial distributions of Na, K, Ca, Mg, Cu, Fe, Mn, and Zn are shown in the maps in September 2022. The examination of the spatial distribution of Ca, Mg, and Na showed that these elements had a similar organisation with high concentrations in the northeast and in the southwest of Oued Souhil groundwater area. However, the spatial distribution of K is high and homogenous in the north of the sector and very low in the south.

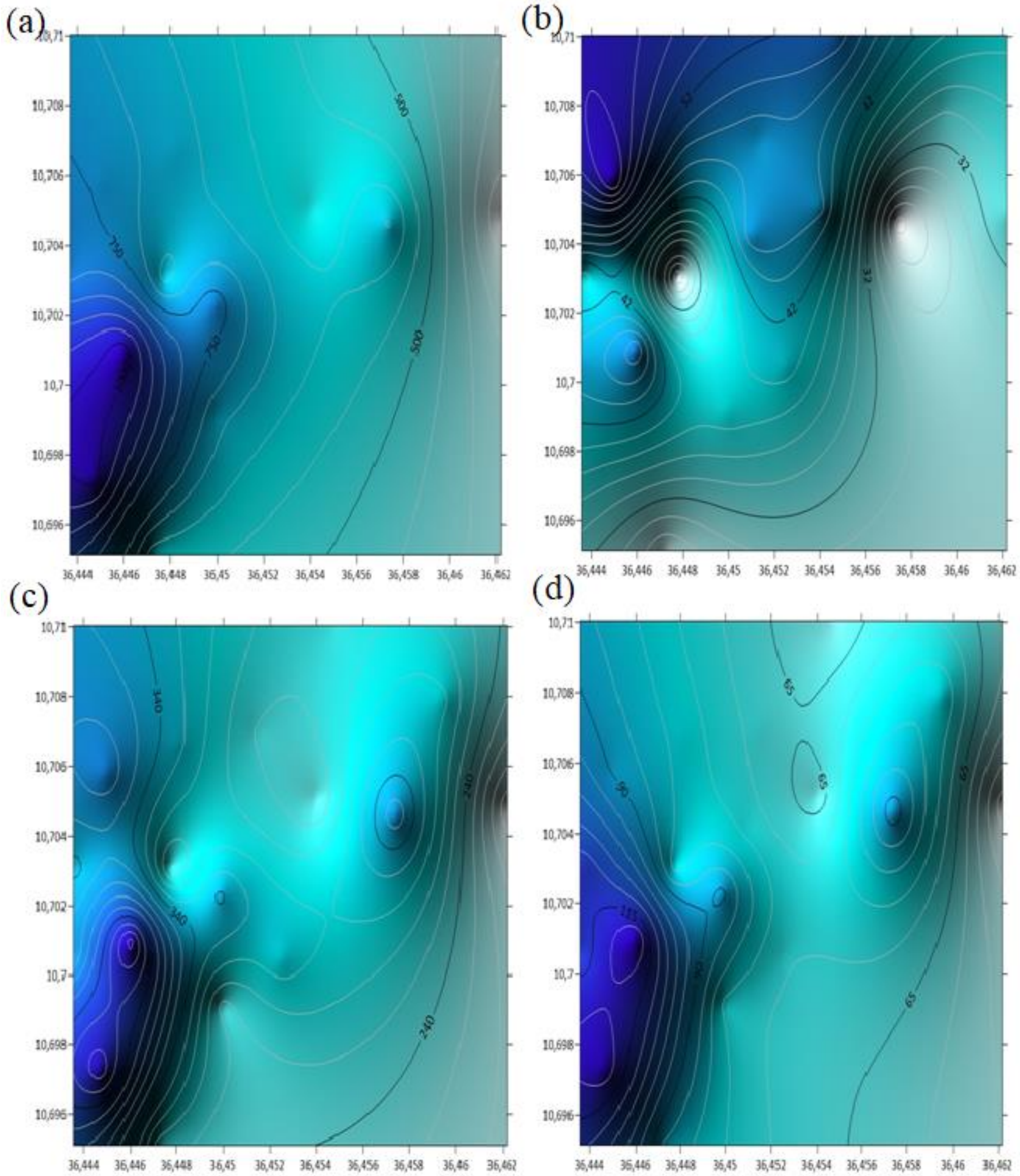

Figure 2: Distribution of (a) sodium Na, (b) potassium K, (c) calcium Ca and (d) magnesium Mg concentrations in Oued Souhil groundwater sector

The amounts of Cu, Zn, Fe, and Mn did not exceed Tunisian standards in groundwater of Oued Souhil area. The spatial distributions of these elements are extremely distinct. An increase in the Cu content in the middle south and in the northeast of the study area was highlighted. Highest Zn concentrations are observed in the middle north, in the Northeast to the southwest part of sector. Fe distribution showed higher amounts in the middle south of the area. Mn concentration map showed that the spatial distribution is high in the North and it decreases towards south of the sector. Mn and K distributions are similar. This high variability in trace element distribution is due to entropic activities (Abiven, 2004).

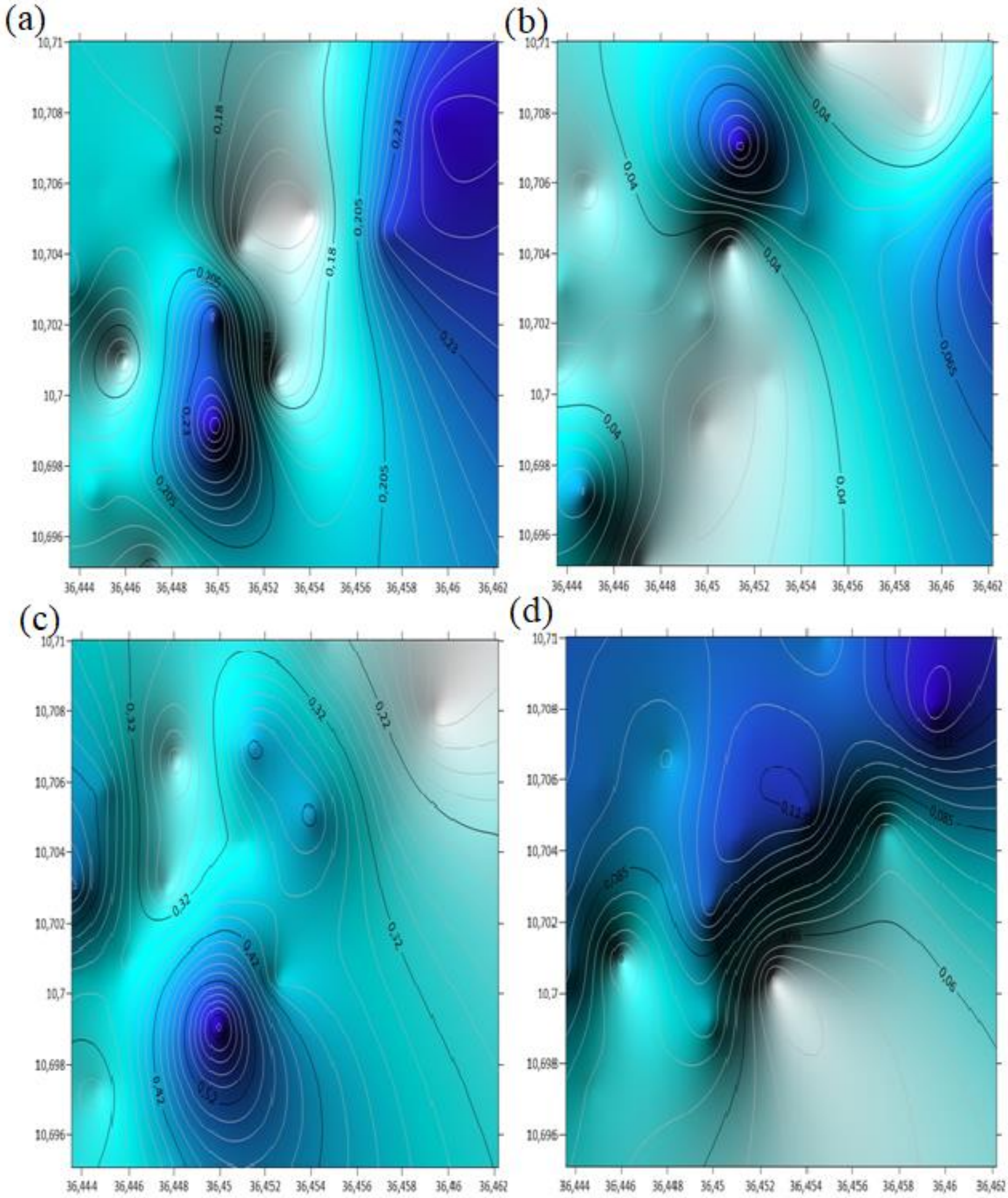

Figure 3: Distribution of (a) copper Cu, (b) zinc Zn, (c) iron Fe and (d) manganese Mn concentrations in Oued Souhil groundwater sector

CONCLUSION

The impact of the irrigation with TWW on the perimeter of Oued Souhil is observed at the long-term after about 40 years of irrigation (since, 1989).

The investigation of the chemical composition Oued Souhil groundwater sector comparing to groundwater out of this area revealed that TWW irrigation and seawater intrusion have changed groundwater status.

We can conclude that more attention should be paid to the impact of these problems for the excess of water and the chemical elements that can be leached and transferred to the groundwater. A continued control of the groundwater contamination must carry out.

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Conflict of Interest:

There is no such evidence of conflict of interest.

Author Contribution

All authors have participated in critically revising of the entire manuscript and approval of the final manuscript.

REFERENCES

Ashraf, I., Ahmad, F., Sharif A., Altaf, A. R., & Teng, H. (2021). Heavy metals assessment in water, soil, vegetables and their associated health risks via consumption of vegetables, District Kasur, Pakistan. *SN Appl Sci*. *3*, 552.

Abiven, S. (2004). Relations entre caractéristiques des matières organiques apportées, dynamique de leur décomposition et évolution de la stabilité structurale du sol. Mémoire de thèse, Biologie et Agronomie, Ecole Nationale Supérieure d'Agronomie de Rennes, 262p.

Dahmouni, M., Hoermann, G., Jouzdan, O., & Hachicha, M. (2019). Spatio-temporal variability of hydrochemical parameters and heavy metals in shallow groundwater of the area of Cebala–Borj–Touil, irrigated with treated wastewater (Tunisia). *Env. Earth. Sci*. *78*, 57.

Elbana, T. A., Ramadan, M. A., Gaber, H. M., Bahnassy, M. H., Kishk, F. M., & Selim, H. M. (2013). Heavy metals accumulation and spatial distribution in long term wastewater irrigated soils. *J Environ Chem Eng*. *1*, 925–933.

FAO (Food and Agriculture Organization of the United Nations). (2012). Coping with water scarcity. An action framework for agriculture and food security, Rome.

Hamilton, A. J., Stagnitti, F., Xiong, X., Kreidl, S. L., Benke, K. K., & Maher, P. (2007). Wastewater irrigation: the state of play. *Vadose Zone J*. *6*, 823–840.

Hashem, M. S., & Qi, X. (2021). Treated wastewater irrigation – a review. *Water*. *13*, 1527.

Kouzana, L., Ben Mammou, A., & Gaaloul N. (2007). Seawater intrusion and salinization in a coastal water table (Korba, Cap-Bon, Tunisia). *Geo-Eco-Trop. 31*, 57-70.

Li, H., Shao, X., Huang, X., & Liao, L. (2007). Advance of research on harm of sewage irrigation in farmland and solving countermeasures. *Water Sav Irrig*. *32*(2), 14–17 (in Chinese).

Lesser-Carrillo, L. E., Lesser-Illades, J. M., Arellano-Islas, S., & GonzalezPosadas, D. (2011). Balance hídrico y calidad del agua subterránea en el acuífero del Valle del Mezquital, México central. *Rev Mex Ciencias Geol*. *28*, 323–336.

WHO (Guidelines for the safe use of wastewater, excreta and greywater) (2006). World Health Organization, *Geneva*, *2*.

Wang, Z., Yang, G., Chen, X., Fe, Y., Zhang, F., & Chen, J. (2008). Groundwater contamination caused by wastewater irrigation and its controlling countermeasures. *Hydrogeol Eng Geol*. *35*(3), 99–103 (in Chinese).

Yin, S., Wu, W., Liu, H., & Bao, Z. (2016). The impact of river infiltration on the chemistry of shallow groundwater in a reclaimed water irrigation area. *J Contam Hydrol*. *193*, 1–9.

Yang, S., Feng W., Wang, S., Chen, L., Zheng, X., Li, X., & Zhou, D. (2021). Farmland heavy metals can migrate to deep soil at a regional scale: a case study on a wastewater-irrigated area in China. *Environ Pollut*. *281*, 116977.

Yadav, R. K., Minhas, P. S., Lal, K., Chaturvedi, R. K., Yadav, G., & Verma, T. P. (2015). Accumulation of metals in soils, groundwater and edible parts of crops grown under long-term irrigation with sewage mixed industrial effluents. *Bull Environ Contam Toxicol*. *95*, 200–206.