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THE USE OF TREATED WASTE WATER IN AGRICULTURE: IMPACT ON SOIL CHARACTERISTICS

L'UTILISATION DES EAUX USÉES TRAITEES EN AGRICULTURE: IMPACT SUR LES CARACTERISTIQUES DU SOL

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ABSTRACT

Nowadays, climate change scenarios predict a rainfall irregularity, which poses the problem of water resources scarcity. The use of unconventional water and in particular treated wastewater in agriculture is one of the adopted remedies. This work studies its impact on soil characteristics. Results showed a slight increase in pH and electrical conductivity which can interfere with the uptake of minerals by plants. As for the content of organic matter and mineral elements, the richness of water in these elements increases it. Likewise, the heavy metal content always remains low and below the standards for the various sites. So, this water can be used in agriculture with regular monitoring of soil characteristics which is recommended.

Key words: treated waste water, irrigation, soil, heavy metals.

RESUME

De nos jours les scenarios du changement climatique prédictent une irrégularité des pluies ce qui pose le problème de rarification des ressources en eau. L'utilisation des eaux non conventionnelles et en particulier les eaux usées traitées en agriculture est l'un des remèdes adoptés. Le présent travail étude son impact sur les caractéristiques du sol. Les résultats ont montré une légère augmentation du pH et de la conductivité électrique qui peuvent gêner l'absorption des éléments minéraux par les plantes. Quant à la teneur en matière organiques et des éléments minéraux, la richesse de l'eau en ces éléments, l'augmentent. De même, le contenu en métaux lourds reste toujours faible et en dessous des normes pour les différents sites. Cette eau est utilisable avec un suivi régulier des caractéristiques du sol est recommandé.

Mots clés : Eaux usées traitées, irrigation, sol, métaux lourds.

INTRODUCTION

Water scarcity is becoming a serious problem during lasts years. A great pressure on water resources was recorded due to the population growth and the increasing demand for irrigated areas. Various sectors are major water consumers like food industry where an export on resource depletion in water is largely offset by Tunisian imports of products agrifood (Ouertani et al., 2016). Also, the water quality was degraded due to the various anthropogenic activities (Adjagodo et al., 2016, Faye, 2017). In many countries there is an anarchic exploitation without strategies, which makes the water resource insufficient for agriculture, drinking water supply and industry (Khemmoudj et al., 2016). Moreover, the climatic changes marked by the diminution of precipitation especially in arid zones aggravate the situation. So, the great challenge for the future period is to provide water resources. Among various solutions, the use of non conventional waters is adopted. Waste water recycling is an important means to fill water shortages and maintain water resources. Particularly as climate change is expanded (Dai et al.. 2018). The reuse of waste water for irrigation of agricultural lands is feasible but after treatments. Wastewater coming from municipal and industry can be used with the respect some norms. Also, the re-utilization of this water contributes to the reduction of some environmental problems due to limiting rejects in the nature and discharging processes in purification station. The treated waste water has many advantages. They contain nutrients and an important level of organic matter which contribute to the soil enrichment. The use of this water is economically of a great important for grower seeing that it reduces the fertilizers supply. Despite these advantages the use of treated waste water showed some inconvenient of social, legislative, economic, sanitary and agronomic orders. As social constraints is the strongly implanted idea in the public mindset due to habits regarding waste water. For legislative aspect, the use of treated wastewater is applicable only in concordance with the country's policy. In Tunisia, the treated waste water is allowed for irrigating only Garden. Golf field, fruit trees and forage with a total interdiction of vegetables (Tunisian standards, 1989). On which concern the economic plan, the carrying out of a wastewater project, requires a detail study of natural resources, water mobilization and degree of pollution. As health aspect, urban effluents are rich in pathogenic microorganisms. Even after treatment, these waters remain loaded with bacteria and viruses that can harm human health to different degrees. For the agronomic aspect, in addition to the plant-friendly nutrients, urban effluents may also contain harmful elements. These waters are always rich in sodium and chloride which cause soil salinization (Ounaies et al., 1992). Levy and Torrento (1995) affirmed that when wastewater is used for irrigation, the presence of Na+ can be harmful to soil structural stability. Also, Liang et al. (2021) showed that long term use of winery waste water irrigation has potential negative effect on soil structural stability through increasing exchangeable K+. As well, treated waste water can presents heavy metals. They include micronutrients such as: Fe. Mn. Cu. Zn and Mo which are essential in soil but in excessive quantities they become harmful. As. Hg. Pb and Cd are also heavy metals even at low concentrations, they are considered harmful to humans and animals which can be arranged according to their toxicity in the following order: Hg > Cu > Zn > Ni > Pb > Cd > Cr > Sn > Fe > Mn > Al (Wang et al. 2003; Pueyo et al. 2004; Filipiak-Szok et al. 2015). So, in this context, the present work consists on the assessment of the soil characteristics irrigated with treated waste water in one of the most irrigated perimeters in Tunisia. It also, evaluates the efficiency of this water which becomes the most important alternative for the coming period.

MATERIAL AND METHODS

Area of studt and sampling

The present work was carried out in the East central region of Tunisia. Precisely in the irrigated perimeter of Ouardanine which belong to the Monastir governorate (Figure 1).

The climate of the region is moderately warm Mediterranean with dry summers. The average temperature in Ouerdanine is 19.4 °C and the annual precipitation is on average 353.7 mm. From each orchard, a number of five points was marked. Soil sampling was done from the horizon 0-60 cm in depth. At each point three replicates were picked up.

The used water is secondary treated waste water from the basin of ‘Ouardanine’ managed by the National Office of Sanitation (ONAS) which characterized by a salinity of 1.9 g/l. An important irrigated perimeter was developed in the region. Some soil characteristics of the studied area are represented in the table 1.

Figure 1: **Localization of the area of the study.**

Table 1: Soil characteristics of the studied area (Active calcite: CaCo, % clay, %limon. % sand)

CaCo (mg Kg^{-1})	<3.00
% Clay	25.53 ±1.67
% limon	16.44 ±2.60
% sand	58.02 ±4.26

Means are presented ± SE (n=15).

Water and soil analyzes

Water samples have been collected in polyethylene bottles from the basin of 'Ouardanine' after filter. A various parameters were determined such as:

Chemical oxygen demand (COD) is one of the main parameters of water quality. It represents the quantity of oxygen necessary to oxidize all the organic matter contained in water.

Biochemical Oxygen Demand (BOD) corresponds to the quantity of dioxygen necessary for aerobic microorganisms in water to oxidize organic matter dissolved or in suspension in water. It designates the potential consumption of oxygen by biological means.

The suspended matter (SM) represents all the insoluble solids visible to the eye present in suspension in water. The more SM is important the more water is said to be turbid.

The soil sampling was done on nine points distributed over three sites in the study area at three depths such as from the 0-20, 20-40 and 40-60 cm horizons. From each one three samples were analyzed.

General properties were also determined for both water and soil which are: pH and electric conductivity (EC).

The pH was directly measured using a JENWAY pH meter. So, soil pH is a measure of acidity in its liquid phase. To determine this measure a 20 g of each sample was added 50 ml of distilled water with mixing. After decantation and filtration the reading was taken using a pH meter.

The electric conductivity is a measure of the ion concentration of water or of the liquid phase of soil using the property of an aqueous solution to conduct electricity in proportion to its ion concentration. For soil sample, it is measured by mixing 10 g of substrate with 50 ml of distilled water. After mixing and filtration through filter paper, the reading was taken using a JENWAY brand conductivity meter.

Organic matter

To determine the organic matter content of the soil. 0.2 g of soil was weighed then 5 ml of potassium dichromate and 10 ml of sulfuric acid were added. After vigorous mixing, it was left to stand for 30 minutes and then 25 ml of distilled water was added. Further mixing took place and left to stand overnight we proceed to spectrophotometer reading with a wavelength of 600 nm along with the standard range.
The organic carbon content was calculated as follows: %MO = %C*1.72 with% C = (ml of Potassium bichromate 1N in excess *0.004*100) / substrate weight

Mineral elements

The determination of K. Na and Ca

We proceed firstly to extraction which performed using 77g of ammonium acetate dissolved in approximately 900ml of water. Then, the pH solution was adjusted to 7 using acetic acid solution. Then it was transferred to a 1 L volumetric flask and adjusted to volume with water and homogenized.5 g of each sample was weighed and 100 ml of the extraction solution was added. Before filtering, the suspension was placed on the stirrer and stirred at a temperature of 20 °C for one hour. The clear filtrate was collected in a clean. dry flask for spectrometric measurement; finally, the calibration solutions and the test solution were performed successively.

The determination of phosphorus content

It is based on the solubilization of the element in a solution of sodium bicarbonate at pH=8.5. This involves preparing 3 reagents:

- To prepare the sodium bicarbonate solution. 42 g of sodium bicarbonate $NaHCO_3$ were weighed. Then it was dissolved in about 900 ml of distilled water and the pH was adjusted to 8.5 with 1N NaOH. Finally, the volume was made up to 1000 ml.
- Then to prepare the Duval reagent. 0.479 g of KH_2PO_4 (potassium dihydrogenphosphate) was added to the P_2O_5 solution at 250 ml. After that, it was left heated in the water bath at 105 ° C for one hour and then 100 ml of distilled water was added.
- Finally. 1% ascorbic acid was prepared and kept it in the cool and light.

For analyzes 2.5 g of soil sieved at 2 mm were taken and 50 ml of 0.5 N sodium bicarbonate pH = 8.5 were added. After stirring for 30 minutes, samples were filtered and 10 ml of the filtrate was taken, then 0.2 ml of sulfuric acid was added. It was left to degas for at least one hour, then 1 ml of Duval reagent and 5 ml of ascorbic acid were added. Before going to the absorbance reading, the prepared samples were put in an oven for 45 minutes at 75 °C. We finished by the absorbance measure using a spectrophotometer at a wavelength of 660 nm. The phosphorus concentration in ppm is the direct reading on the calibration curve.

The determination of some micronutrients and heavy metals

A 0.5 g of air-dried soil sample was weighted into a digestion tube. The mixture of 1:3 acids (HCl: HNO_3) was added. The digestion tubes were then placed on oven and heated for 3 h. All the digests were cooled and filtered using Whatman filter paper and diluted to 50 ml by distilled water. The instrument was calibrated using calibration blank and series of working standard solutions of each element to be analyzed. The digested samples were determined for the concentrations of elements using flame atomic absorption spectrophotometer.

Statistical analysis

Analysis of variance of the data was performed using the SPSS statistic software (20.0). A minimum of three replicates were used for determinate the mean and standard deviation of each presented value.

RESULTS

Water quality

The pH is neutral and it is around 7.7 (Table 2). The electric conductivity is of 276.7 which is below 700 Ms/m the tolerated value. By examining the other parameters which are accepted by the Tunisian standards so the treated waste water is allowed to the use in irrigation. It is the case of the studied zone. Moreover, the COD, BOD and MS are in the standards. Also, the salinity which determined through the sodium and the chlorure content showed that are of 251 and 388 mg/l respectively. The sodium concentration in irrigation water is estimated by the sodium absorption ratio (SAR) which describes the amount of sodium in excess relatively to the Ca^{++} and Mg^{++} which can be tolerated by relatively large amount in irrigation water. In this case the SAR is above 4.

Table 2: Treated waste water analyzes and Criterion following Tunisian Standards NT 106.03 Environment protection: Use of treated waste water in agriculture (1989).

Parameters	Values	Unit	Criterion
pH	7.7 at 22.2°C	-	6.5<pH<8.5
Electric conductivity	276.7 at 25°C	Ms/m	700
COD	62	mg/l	90
BOD	12	mg/l	30
MS	20	mg/l	30
Chlorure	388	mg/l	2000
Ammoniacal nitrogen	15.69	mg/l	-
Sodium	251.0	mg/l	-

Moreover, the analysis showed that the treated waste water is devoid of nematods so it represents no contamination risks.

Soil characteristics

Concerning the electric conductivity, it was showed that it differ from one site to other. In fact, it is more important in site 1 and site 2 comparatively to the third one which ranged between 300 and 429. The determination of pH showed that is more than 7 (Table 3). In the site 1 it ranged between 8.3 and 8.5 for different depths. For the other sites it is above 8 with no significant differences between horizons. By examining the presented values, it is noted that a positive correlation was found between EC and pH which reflects the richness of soil with mineral elements.

Table 3: Electric conductivity (EC) and pH of soil in different sites

Sites	Depth (cm)	EC (µS cm^{-1})	pH
Site1	0-20	800 ±1.30	8.35 ±0.53
	20-40	460 ±0.72	8.36 ±0.48
	40-60	300 ± 0.26	8.58 ± 0.35
Site 2	0-20	724.5±0.00	7.93±0.11
	20-40	414.5±2.12	8.47±0.09
	40-60	578±0.00	7.95±0.14
Site 3	0-20	429±80.60	7.90±0.12
	20-40	339±0.70	7.30±0.67
	40-60	300±0.00	7.58±0.17

The determination of organic matter content in the soil showed differences although between sites and between soils horizons (table 4). In the site 1 the average value of organic matter is about 4.5% with no significant difference between horizons. However, in site 2 and site 3 values were more important and decrease with the depth.

Table 4: Organic matter content of the soil in different sites.

Site	Depth (cm)	Organic matter (%)
Site1	0-20	4.86 ± 0.437
	20-40	4.56 ± 0.237
	40-60	4.50 ±0.749
Site 2	0-20	2.03±0.1
	20-40	1.71±0.4
	40-60	1.80±0.1
Site 3	0-20	3.64±0.00
	20-40	2.72±0.00
	40-60	1.28±0.01

The determination of some mineral content of soil showed slight differences between sites (Table 5). The concentration of Ca in soil is more important in site 1 compared to the average of site 2 and 3 with no significant differences between horizons. In addition, the phosphorus concentration is less important in site 1 with an increase concentration in deeper horizons. As well, it was noted that Na and K values are close.

Table 5: Mineral elements concentrations in soil of different sites.

Sites	depths (cm)	Na ($mgKg^{-1}$)	Ca($mgKg^{-1}$)	K($mgKg^{-1}$)	P (ppm)
Site1	0-20	9.48 ±1.17	202.91± 2.91	10.60 ±1.98	0.001±0.00
	20-40	11.15±0.38	212.08± 3.75	8.70± 0.77	0.002±0.00
	40-60	13.46 ±1.15	220 ±3.33	8.24±1.38	0.002±0.00
Site 2	0-20	10.00±0.00	44.00±0.00	8.63±0.00	0.14±0.03
	20-40	13.75±1.76	29.85±0.21	7.04±0.64	0.16±0.00
	40-60	14.37±0.88	48.90±0.09	6.47±0.16	0.14±0.00
Site 3	0-20	10.01±0.01	44.55±0.00	8.6±0.01	0.17±0.00
	20-40	12.50±0.00	28.01±0.01	7.5±0.01	0.16±0.00
	40-60	13.70±0.01	47.72±0.00	6.36±0.00	0.14±0.00

Concerning the content of soil in some micronutrients and heavy metals values are shown in table 6. The concentrations of Hg, Ni and Cd are insignificant for both sites. For the Cu, Zn, Fe, Mn and Mg the concentrations are close and differences are negligible.

Table 6: Average values of some heavy metals and micronutrients concentration in soils for orchards irrigated with treated waste water in the 0-40 layers.

	Hg mg/Kg	Cu mg/ Kg	Zn mg/ Kg	Ni mg/ Kg	Cd mg/ Kg	Fe mg/ Kg	Mn mg/ Kg	Mg mg/ Kg
Site 1	<0.01	2.81 ±0.31	7.17 ±1.49	<0.01	<0.01	2.43 ±0.54	7.30 ±1.42	459.9 ±11.87
Site 2	<0.01	3.26	9.28	<0.01	0.015 ±0.000	1.66	5.29	443

Means are presented ± SE.

DISCUSSION

Water analyzes showed that the secondary treatments improve the quality. In fact the treated waste water used for irrigation is in the standards published by the Tunisian government. This is useful for irrigation because alkalinity is in the limit but according to Couture (2004) it is very important to "break" by acid addition this alkalinity which prevents calcium and magnesium from being available to the plant. Also, it avoid the carbonates transformation into calcium and dolomitic lime ... which can causes leaves deposits and clog sprinkler or drip systems. Knowing that pH strongly influences the availability of nutrients in irrigation water for plants. In overall, the irrigation water pH should be between 5.5 and 6.5 to these values the solubility of most required microelements is optimal. Gargouri (1998) noted that the irrigation with treated waste water didn't affect soil and pH ranged between7.0 and 8.5 which are acceptable for olive trees. Also, Tarchouna et al. (2010) showed that treated waste water slightly increased soil pH comparatively to fresh water. The electric conductivity is under limit so it didn't cause a problem in irrigation. For the chlorure, sodium and ammoniac nitrogen concentrations are low and they didn't affect the absorption in the root zone. Referring to Couture (2004), it was revealed that sodium is one of the most undesirable elements in irrigation water. This element is originated from the alteration of the rock and soil or seawater intrusions. It negatively affects water and soil quality and irrigation systems. In fact, it replaces Ca^{++} and Mg^{++} adsorbed on clay particles and causes dispersion of soil particles. Consequently a soil alteration takes place due to a hard and compact soil particularly when it is dry or excessively waterproof. The permeability changes with soil texture such as: sandy soils may not deteriorate as fast as heavier soils in the case of the use of high sodium water. In general, the sodium content contributes directly to the total salinity of the water and can be toxic to sensitive crops. Various plant responses can be noted for example plant defoliation, slow growth and physiological process dysfunction (Abbassi et al., 2014).

Water with an SAR of more than 9 is harmful but it can be used even if the total salt content is relatively low. As well, a continuous use of water with a high SAR induces the soil to break down. When the SAR is between 6 and 9, the risk of problems related to patency of the soil increase. However, water with an SAR between 0 and 6 can generally be used in all soil types but sodium accumulation can be occurred. Therefore, irrigation water with salinities between 1.5 and 3.00 mS / cm with an SAR above 4 should be used with caution. So, the problem of water salinity as treated waste water can be used while taking into account the type of soil and the tolerance of the cultivated crop. Among the criteria of water quality is the richness in mineral elements but with a certain limit because some ones can be directly toxic to the crop and microorganisms in soils. Couture (2004) revealed that establish toxicity limits for irrigation water is complicated by the reactions that can occur when the water reaches the ground). The potentially hazardous elements in the water can be inactivated by chemical reactions or accumulate in the soil to enhance plants toxicity.

In overall, the use of treated waste water affects the organic matter content in soil. A decrease by going deep was recorded which previously affirmed by Tarchouna et al. (2010). They found that organic matter content of sandy soil decreased from 1.25% to 0.65%. Concerning the mineral element content, results showed that values are close except potassium which concentration decrease with depth. This is confirms the constatation of Nyamangara and Mzezewa (2000). They affirmed that the richness of treated waste water with potassium causes its accumulation in upper horizons which move slowly in the soil profile.

As it is known as treated waste water presented an important heavy metals content which affect soil. The present results prove that even after long term the irrigation using treated waste water slightly increase the soil content of micronutrients and heavy metals for this reason growers didn’t use fertilizers. In recent years, many researches related to the wastewater impact on soils particularly the contamination with heavy metals were published. Mahmood and Malik (2014) and Zwolak et al. (2019) showed that wastewater irrigation has changed physical and chemical properties of the soil and led to heavy metal uptake. Moreover Galal (2015) affirmed that treated waste water induced the accumulation of K, Fe, Mn, Cu, Zn, Ni and Na in the soil. In another hand, it was affirmed by Traore et al. (2015) that Bioconcentration factors show that heavy metals found in prawns come from waters and sediments as well as food they consume in some regions despite that are no waste water.

CONCLUSIONS

Results showed that the use of treated waste water may be a solution to cope water scarcity due to the slight content of nutrients and heavy metals. The secondary treatment of waste water improves the water quality. In addition, the use of this water reduces the fertilizers input. This does not prevent the following of soil characteristics through analyzes. It must be done more frequently to avoid the accumulation of unwanted material in the soil.

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