# EFFECTS OF TREATED WASTEWATER IRRIGATION ON LEMON TREES

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**Abstract**

This research is focused on evaluating the effects of applying treated wastewater on citrus trees. Two experimental plots irrigated with two different treated wastewater effluents were compared. The experimental sites were located in Murcia, in the south-east of Spain. The first experimental plot is in Cartagena, in the south-east of Murcia, where the treated wastewater comes from a secondary treatment plant and the soil was a silt-loam. The second experimental plot is Campotejar, in the north-east of Murcia, where the treated wastewater comes from a tertiary treatment plant and the soil was silt-clay. Soil, leaf, and water chemical and microbiological analyses were performed in order to detect these effects. The physical parameters pH, EC, turbidity and total dissolved solids (TDS) were higher in Cartagena´s treated wastewater than in Campotejar´s, which has higher levels of nitrates, sulphates and suspended solids (SS). High accumulation of K, Fe, P and some heavy metals like Ni, Cr and Pb in Cartagena´s soil were incorporated in the leaf mineral status, whereas high accumulation of chlorides in Campotejar´s soil were reflected in this site´s leaf mineral status. The microbiological analysis revealed an absence of E.Coli and helminth eggs in the treated wastewaters and soils, but in Cartagena´s treated wastewater fecal coliforms exceeded health standards. The lemon biomass yield was higher in Cartagena than Campotejar. Some negative effects were observed in the plants canopy due to salinity from the application of treated wastewater.

**Keywords:** treated wastewater reuse, irrigation, plant and soil effects.

## Introduction

In many parts of the world, treated wastewater has been successfully used for the irrigation, and many researchers have recognized its benefits (Mujeriego and Sala, 1991; Levine and Asano, 2004). In the Mediterranean countries, treated wastewater is increasingly used in areas with water scarcity and its application in agriculture is becoming an important addition to water supplies. However, reclaimed wastewater application may create undesirable effects in soils and plants with direct effects on soil suitability for cultivation and water resources availability. Current water quality criteria for agricultural reuse have mainly focused on total dissolved solids (TDS), salinity aspects (Ayers and Wescot, 1994), and the microbiological factors that may cause sanitary problems (WHO,1989). More specific water quality parameters for the reuse of reclaimed wastewater are presented by Levine and Asano (2004).

The reuse of treated wastewater is a good option for increasing water supplies to agriculture. One of its benefits is the plant's use of the water's nutrients and therefore a reduction in the pollution load that wastewater contributes to the surface water supply (Zekri and Koo., 1994). There is considerable interest and concern in the long-term effects of reclaimed wastewater on crops intended for human consumption. As a result, this research has been conducted to evaluate the effects of reclaimed wastewater on citrus trees. The objective of this research is to compare two sources of treated wastewater, one obtained with a secondary treatment and the other with a tertiary treatment, in two different locations in Murcia and to study their effects on soil chemical properties and in the leaf mineral status.

## Methods

The experiment was conducted during 2006 in two locations in the Region of Murcia, Cartagena and Campotejar. Cartagena´s experimental plot is located in San Felix, a small village 4 Km in the north of Cartagena (37º3´N, 0º58´W). The orchard size is 12 ha with "Fino" lemon tree grafted on "Macrophyla" rootstock. The tree age is 7 years and the plant spacing 7x5 meters. The irrigation is drip irrigation by eight compensated pressure drips per tree, each with a flow rate of 4 $L.h^{-1}$. Campotejar´s experimental plot is located 7 km in the north of Molina de Segura (38º07´N, 1º13´W). In this case the orchard size is 10 ha with the same crop (variety and rootstock), trees age, plant spacing and the irrigation techniques as Cartagena´s plot. The average annual precipitation in Cartagena and Campotejar ranged between 200 and 300 mm. The average temperature in Campotejar was 19,7 ºC and in Cartagena was 18,7 ºC. During the season of the experiment the mean daily reference evapotranspiration in Cartagena was 3,87 mm and in Campotejar 3,41 mm. The sites soil are silty-loam in Cartagena and clay-loam in Campotejar.

The greatest difference between the two experimental plots was the origin and the quality of the water used in irrigation. In Cartagena treated wastewater (TWW) with a secondary treatment from the Cabezo Beaza treatment plant was used, while in Campotejar TWW with a tertiary treatment from the Molina Norte treatment plant was used but was mixed with well water in equal proportions.

To characterize irrigation water quality in both sites during 2006, monthly water measures of the water used were collected. Trimestal leaf analyses were carry out in 48 trees in a randomized block design in both sites. Semestral soil analyses were made in a humid bulb to see the effects of wastewater irrigation.

## Results and Discussion

### Water analysis

In both cases the irrigation waters are hard with a slightly high pH level, and so it would be interesting to apply a corrector acid to avoid magnesic and calcic precipitation (Pitts, 1996). These precipitates create drip clogging, the main problem in the reclaimed wastewater use in drip irrigation. Salinity problems appear when the electric conductivity (EC) of the irrigation water is higher than 1.5 dS/m, and both types of water fail to fulfill all the necessary requirements for their use (Table 1). This problem is especially serious for lemon trees, which are considered sensitive crops to salinity (Mass, 1993). The high observed level of electric conductivity in our trials was primarily due to the high concentration of chlorides in both locations (Table 1). High levels of boron were also observed in Cartagena´s irrigation water. This excess boron can cause phytotoxic problems in citrus trees (Chapman, 1968). In numerous articles it has been demonstrated that boron reduces tree growth and productivity, and contributes to defoliation and yellow leaves (Aucejo et al., 1997). In Campotejar boron levels were normal, nevertheless a high sulphate concentration was observed (Table 1). The analysis of both types of irrigation water show clear differences in their composition. Cartagena´s irrigation water show higher values in pH, EC, total dissolved solids (TDS), turbidity and hardness (Table 1). This water has a higher concentration in chlorides, magnesium and boron (Table 1). In general, most of the analyzed elements in Cartagena´s irrigation water show a higher concentration than in Campotejar. This fact results in large part from Campotejar's use of a 50% well-water mix with the treated wastewater. Campotejar´s irrigation water microbiology quality is good because it had absence of microbiology toxicity indicators. In Cartagena´s reclaimed wastewater high levels of faecal coliforms were observed (Table 1), exceeding the maximum concentration ranges for use in irrigation water recommended by the World Health Organization (WHO,1989) and the U.S. Environmental Protection Agency (EPA, 2004). Finally, we can conclude by saying that the mix between Campotejar´s reclaimed wastewater and well water has a better agronomic quality than Cartagena´s reclaimed wastewater.

## Soil and leaf analysis

The soil grain size analysis was carried out by the laser diffraction. According to the texture-triangle of the U.S. Department of Agriculture, the soil was classified as silty loam in Cartagena and silty clay in Campotejar. The pH of the soil samples was found to be within the range of 6.6 to 8.4, which is the most desired range in agricultural soils. Both soils were classified as normal soil with respect to salinity and sodicity hazards. Reclaimed wastewater use does not generate an important increase in soil organic matter and macronutrients level. In micronutrients and heavy metals, it is important to emphasize the high soil boron concentration founded in both locations.

***Table 1: Physical-chemical and microbiological analysis of irrigation water used in both locations. The data contain average values derived from all the samples collected and analyzed during the 2006 year.***

| Macroelements (ppm) | Cartagena | Campotejar | Optimum range |
|---|---|---|---|
| P | 2.06 | 0.27 | <5 |
| K | 42 | 25 | <100 |
| Ca | 107 | 69 | <200 |
| Mg | 70 | 41 | <60 |
| S | 102 | 65 | <150 |
| **Microelements (ppm)** | **Cartagena** | **Campotejar** | **Optimum range** |
| Fe | 0 | 0 | <1.5 |
| Na | 334 | 311 | <900 |
| B | 1.39 | 0.84 | <1 |
| Mn | 0 | 0 | <1.5 |
| **Heavy metals (ppm)** | **Cartagena** | **Campotejar** | **Optimum range** |
| Ni | 0.12 | 0.11 | <2 |
| Cd | 0 | 0 | <0.05 |
| Cr | 0 | 0 | <1 |
| Cu | 0 | 0 | <5 |
| Pb | 0 | 0 | <10 |
| Zn | 0.11 | 0 | <10 |
| **Anions (ppm)** | **Cartagena** | **Campotejar** | **Optimum range** |
| Fluorures | 0.56 | 0.50 | <1 |
| Chlorides | 221 | 170 | <100 |
| Nitrates | 3.86 | 5.91 | <50 |
| Phosfates | 3.10 | 0.30 | <15 |
| Sulphates | 354 | 529 | <400 |
| **Parámeters** | **Cartagena** | **Campotejar** | **Optimum range** |
| pH | 8,28 | 7,94 | 6,5-8,5 |
| EC (dS/m) | 2,82 | 2,1 | <1,5 |

| | | | |
|---|---|---|---|
| TDS (mg/l) | 1589 | 487 | 450-2000 |
| OBD (mg/l) | 4 | 4 | <30 |
| OQD (mg/l) | 39 | 30 | <120 |
| DO (mg/l) | 5 | 4 | >3 |
| Turbidity (NTU) | 6 | 2 | <5 |
| SS (mg/l) | 17 | 22 | <35 |
| HARDNESS (ºF) | 56 | 34 | >30 duras |
| SAR | 6 | 9 | <9 |
| **Microbiological parámeters** | **Cartagena** | **Campotejar** | **Optimum range** |
| Faecal Coliforms (UFC/100ml) | 4,3 x $10^{2}$ | 0 | 200 |
| E.Coli (UFC/100ml) | 0 | 0 | 1000 |
| Helmints eggs (h/10l) | 0 | 0 | <1 |

*Tabla 2: Physical-chemical and microbiological analysis of soils in both locations. The data contain average values derived from all the samples collected and analyzed during the 2006 year.*

| Organic matter | Cartagena | Campotejar |
|---|---|---|
| Organic matter (%) | 1,38 | 1,59 |
| **Macroelements** | **Cartagena** | **Campotejar** |
| N (%) | 0.08 | 0.10 |
| P (ppm) | 929 | 426 |
| K (ppm) | 10334 | 5707 |
| Ca (ppm) | 114210 | 225270 |
| Mg (ppm) | 11845 | 12679 |
| S (ppm) | 402 | 533 |
| **Microelements (ppm)** | **Cartagena** | **Campotejar** |
| Fe | 11648 | 7063 |
| Na | 1183 | 900 |
| B | 260 | 234 |
| Mn | 342 | 264 |
| **Heavy metals (ppm)** | **Cartagena** | **Campotejar** |
| Ni | 16 | 9 |
| Cd | 0 | 0 |
| Cr | 24 | 11 |
| Cu | 95 | 72 |
| Pb | 87 | 29 |
| Zn | 69 | 60 |
| **Anions (ppm)** | **Cartagena** | **Campotejar** |
| Fluorures | 244 | 167 |
| Chlorides | 2063 | 1381 |
| Nitrates | 402 | 346 |
| Phosfates | 838 | 899 |
| Sulphates | 839 | 887 |
| **Parameters** | **Cartagena** | **Campotejar** |
| pH | 7,84 | 7,93 |
| EC (dS/m) | 0,178 | 0,107 |
| **Microbiological Parameters** | **Cartagena** | **Campotejar** |
| Total Coliforms | 7,3 x $10^{3}$ | 0 |

| | | |
|---|---|---|
| (UFC/100ml) | | |
| E.Coli (UFC) | 5 | 0 |
| Helmints eggs (h/10l) | 0 | 0 |

The higher microbiology load in Cartagena´s reclaimed wastewater generates an increase in total coliform soil values in this location. In Campotejar these coliforms were not observed (Tabla 2). Some researchers claim that reclaimed wastewater is an important source of nitrogen for citrus trees (Zekri and Koo, 1994; Parsons and Wheaton, 1996). In this experiment, it was observed that foliar nitrogen levels are in the optimum range considered for citrus trees development (2,5-2,8%) (Legaz et al., 1995) (Table 3). Boron toxicity levels in citrus fruit have been published by Chapman (1968). Leaf boron content is between 100-130 ppm, which is usually considered the limit for primary toxicity symptoms, whereas boron concentration levels between 200-250 ppm are considered phytotoxic. It has been published as well that high pH in water aids boron absorption by the roots. High levels of chlorides in citrus trees can cause a reduction in vegetative growth and a decrease in the leaf gas exchange (Walker et al., 1982). In spite of high soil boron levels , and high electric conductivity and chloride concentration in both types of water, leaf salt toxicity symptoms were not observed. The leaf macro-nutrient, micro-nutrient and heavy metals concentrations were always in the normal range.

*Tabla 3: Leaf analysis. The data contain average values derived from all the samples collected and analyzed during the 2006 year.*

| Macroelements | Cartagena | Campotejar |
|---|---|---|
| C (%) | 40,66 | 41,77 |
| N (%) | 2,71 | 2,75 |
| P (ppm) | 1192 | 1067 |
| K (ppm) | 15670 | 8598 |
| Ca (ppm) | 45276 | 45264 |
| Mg (ppm) | 3126 | 2596 |
| S (ppm) | 2885 | 2497 |
| **Microelements (ppm)** | **Cartagena** | **Campotejar** |
| Fe | 195 | 111 |
| Na | 148 | 106 |
| B | 42 | 27 |
| Mn | 27 | 30 |
| **Heavy metals (ppm)** | **Cartagena** | **Campotejar** |
| Ni | 4 | 0 |
| Cd | 2 | 32 |
| Cr | 12 | 51 |
| Cu | 13 | 14 |
| Pb | 16 | 0 |
| Zn | 53 | 60 |
| **Anions (ppm)** | **Cartagena** | **Campotejar** |
| Fluorures | 407 | 323 |
| Chlorides | 659 | 870 |
| Nitrates | 455 | 205 |
| Phosfates | 1540 | 1243 |
| Sulphates | 864 | 916 |

## Conclusions

- Microbiology quality indicators in Cartagena´s reclaimed wastewater exceed the recommended limits by the World Health Organization (WHO,1989) and the Environmental Protection Agency (EPA, 2004). The possibility of using reclaimed wastewater mixed with well water (Campotejar) is a good solution for improving the agronomic quality of TWW.

- The high salinity and boron concentrations are the main problems associated with TWW use in the Region of Murcia. Although leaf toxicity levels were not observed, salts accumulation can be a decisive parameter for the lemon crop.

- In both locations, a contribution of macronutrients and organic matter was not observed within a short time by the TWW application in the soils. An increase of pH was generated in both soils.

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## References

Asano T, Levine D (1995).Wastewater reclamation, recycling and reuse: past, present and future. International Association on Water Quality Second Int. Symp. on Wastewater reclamation and Reuse, 17–20 October 1995, Iraklio, Greece; 5-17 p.

Ayers RS, Westcot DW (1994). Water quality for agriculture. FAO irrigation and drainage paper, vol. 29. Rome: FAO; 174 pp.

Aucejo A., J. Ferrer, C. Gabaldón, P. Marzal y A. Seco. (1997). Toxicity in citrus plantations in Villareal, Spain. Water, Air and Soil Pollution, nº 94, 349-360 p.

Chapman H. D. (1968): "The mineral nutrition of *Citrus*", en W. Reuther, L.D. Batchebor, H.J. Webber (eds), The Citrus industry, II, 127-274 p.

EPA (2004). Guidelines for water reuse. Washington DC, USA: U.S. Agency for International Development; EPA/625/R-04/108, 180 pp.

Levine A, Asano T (2004). Recovering sustainable water from wastewater. Environ Sci Technol; 201A.

Legaz, F., M. D. Serna, P. Ferrer, V. Cebolla y E. Primo-Millo (1995): "Análisis de hojas, suelos y aguas para el diagnóstico nutricional de plantaciones de cítricos. Procedimiento de toma de muestras". Generalitat Valenciana. Consellería de Agricultura, Pesca y Alimentación.

Lubello C, Gori R, Nicesse FP, Ferrini F (2004). Municipal-treated wastewater reuse for plant nurseries irrigation. Water Res;38(12): 2939–47 p.

Mass E. V.(1993). Salinity and citriculture. Tree Physiol. nº 12,195-216 p.

Mujeriego R, Sala L (1991). Golf course irrigation with reclaimed wastewater. Water Sci Technol;24(9):161–72 p.

Parsons L. R., T. A. Wheaton (1996): "Florida citrus irrigation with municipal reclaimed water", Proc. Int. Soc. Citriculture nº 2, 692-695 p.Pescod, M.M. (1992). Wastewater treatment and use in agriculture. FAO Irrig. & Drain. Paper No. 47, Roma.

Pitts, D. (1996). Causes and prevention of emitter plugging. Micro Irrigation System Management (module6), University of Florida. 26 pp.

Walker R.R., E. Törökfalvy y W. J. S. Downton (1982): "Photosynthetic responses of the citrus varieties rangpur lime and etrog citron to salt treatment". Australian J. of Plant Physiol, nº 9, 783-790.

WHO (1989). In: Cairncross S, Mara D, editors. Guidelines for the Safe Useof Wastewater and Excreta in Agriculture and Aquaculture. Geneva, Switzerland: World Health Organisation; 194 pp.

Zekri M., R.C.J.Koo (1994): "Treated municipal wastewater for citrus irrigation", Journal of Plant Physiology.