

Effects of brewery wastewater irrigation on Antofagasta soils

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Abstract

Saline soils, common to the Antofagasta region of Chile, limit agricultural activity, the use of phytoremediation and the development of energetic crops. The aim of this work was to evaluate the effects of leaching with brewery wastewater and distilled water on the soil profile by using column assays in order to improve the conditions of saline soils by removing salts. Conductivity and pH were measured in leachate samples and in the soil profile. The results showed that the application of distilled water and brewery wastewater had similar effects, although different in their magnitude, on the conductivity and pH in the soil leachates, but caused different behavior in these variables in the soil profile. The pH values in leachate samples increased from 7.5 to 8.5 and from 8.3 to 9.2 when distilled water and brewery wastewater were used. Conductivity decreased from 18 to 3 mS/cm and from 18 and 7 mS/cm when distilled water and brewery wastewater were used. Distilled water maintained the pH around 8.3 in the soil profile meanwhile the use of brewery wastewater kept the pH around 7.3. Both irrigation solutions decreasing the conductivity in the soil profile reached values between 0.8 and 2.1 mS/cm. It was possible to decrease the conductivity of the soil profile by using distilled water and brewery wastewater as an irrigation solution, although brewery wastewater had high initial conductivity (4.7 mS/cm). In addition, brewery wastewater enabled the pH to be kept constant (around 7.3) in the soil profile. The result indicated that brewery wastewater may be used in the first stage to improve the quality of the saline soil of the Antofagasta Region.

Key words

Irrigation, saline soil, conductivity, brewery wastewater, pH.

Introduction

In the arid zones of northern Chile, the salinity of soils and the availability of water resources are common problems that limit agricultural activities. In addition to salinity, another problem associated with these soils is the lack of organic matter. The climate of the study area is extremely arid with an annual average rainfall of approximately 4 mm and a high UV index. The main daily temperature is 13°C in winter and 20°C in summer (Vargas 2000). Excessive amounts of salts have adverse effects on the physical and chemical properties of soil, microbiological processes and on plant growth (Tejada *et al.* 2006). The soils of the Atacama Desert (Electrical Conductivity (EC) > 10 mS/cm) are characterized as saline soils (Godoy-Faúndez *et al.* 2008). In Chile, studies on arid soils have mainly focused on the remediation of soils contaminated with heavy metals or fuel by mining operations; few studies have been performed on saline soils for agricultural purposes.

Irrigation with fresh freshwater would be an ideal option for improving saline soil quality, but since freshwater resources are scarce, wastewater represents an alternative water source. Some wastewaters are a potential fertilizer when used to irrigate arid zones. They contain organic matter and macronutrients, which is highly beneficial. The aim of this work was to evaluate the effects of leaching with brewery wastewater and distilled water on soil profile using columns assays, to improve the conditions of saline soils by removing salts.

Methods

Soil Samples

Surface soil samples (0-30 cm) were obtained from the commune of Antofagasta. The soil was dried at 65°C for 48 hours and passed through a 2 mm mesh. The pH and EC were determined using saturation extract. Soil pH and EC were measured using a Bench pH/Conductivity Meter Oakton. Organic matter and water content were determined according Sadzawka *et al.* (2006).

Brewery wastewater

Brewery wastewater was obtained from the brewery industry. The properties of the wastewater, such as pH, EC, chemical oxygen demand (COD), color, volatile solids (VS) and total solids (TS) were determined. EC and pH were measured using a Bench pH/Conductivity Meter Oakton. Color was measured at a 455 nm wavelength (Hach Spectrophotometer). COD, VS and TS were determined according to APHA (2002).

Leaching assay

To perform the soil column leaching experiment, plastic columns (25.2 cm length and 5.2 cm internal diameter) were used, filled with approximately 0.4 kg soil and 0.4 kg gravel (ratio 1:1), achieving a bulk density of $1.628 \times 10^{-3} \text{ kg/cm}^3$. The columns were connected at the output to a peristaltic pump (Masterflex) with an outflow rate of $1.4 \text{ cm}^3/\text{min}$. The leaching column experiments were done in three replicates at a room temperature of 19-20 °C (Navia *et al.* 2005).

The soil columns were leached with distilled water and with wastewater and the columns were saturated at the beginning of the irrigation assays, and a 5 cm irrigation solution level was maintained on the top of each soil column. Leachate samples of 100 mL were collected for EC and pH analysis. After leaching was completed, the soil columns were allowed to drain free, and then cut into 5 sections of 3.5 cm each, from the top of the column downwards. Soils samples were dried at 65°C for 48 hours and were analyzed for pH, EC.

Statistical analysis

All data reported are the means of three determinations. Conductivity and pH in the different soil profile were analyzed by analysis of variance. Significant differences were determined at $P \leq 0.05$.

Results and Discussion

Table 1 shows the physicochemical characterization of the Antofagasta soil. The organic matter content was low (< 0.5%), associated with the extreme aridity of the zone due the lack of precipitation and the high level of evaporation. The characterization of brewery wastewater is given in Table 2. Brewery wastewater has a high COD value directly related to the color associated with the organic compounds generated by this kind of industry. The pH was highly alkaline.

Table 1. Characterization of the Antofagasta soil

Parameter	Conductivity (mS/cm)	pH	Water content (%)	Organic matter (%)
	5.03±0.4	7.13±0.1	0.21±0.02	< 0.5

Table 2. Characterization of the brewery wastewater

Parameter	Conductivity (mS/cm)	pH	Total solid (g/L)	Volatile solid (g/L)	COD (mg/L)	Color (UPt-Co)
	4.7±0.3	10 ±0.01	10.07±0.3	7.7±0.9	10.800	1068±6

The variation of pH in the leachate samples using distilled water and brewery wastewater are shown in Figure 1. When both solutions were used, an increase in pH values from 7.5 to 8.5 was observed in the leaching samples with distilled water, and from 8.3 to 9.2 with brewery wastewater.

The variation of pH in the soil profile using both irrigation solutions is shown in Figure 2. It was observed that the pH value in the soil profile with the distilled water irrigation decreased in depth (from 8.4 to 8.1), whereas using brewery wastewater the pH was constant around 7.3.

For the use of distilled water, an increase in the pH of the leaching samples was noted, as was a decrease in the pH values in the soil profile. This may be attributable to the release of OH⁻ ions from the soil. In the case of brewery wastewater, the pH value in leaching samples increased, whereas the pH value in the soil profile was constant, with a tendency to increase. The organic matter present in brewery wastewater acts as a buffer, keeping the pH value constant (Tan 1993).

The variations in the conductivity of the soil leaching samples are shown in Figure 3. A decrease in the conductivity values was observed with an increase in the volume of the irrigation solution. The conductivity values present in the leachates of brewery wastewater were higher (ranging between 18 and 8 mS/cm) than leachates from distilled water (ranging between 18 and 4 mS/cm). This can be explained by the initial conductivity of brewery wastewater.

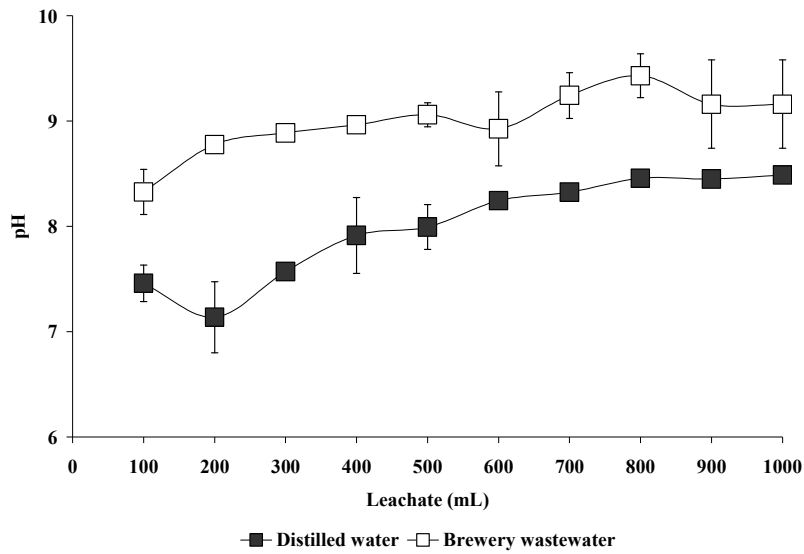


Figure 1. Variation of pH in the soil leachates.

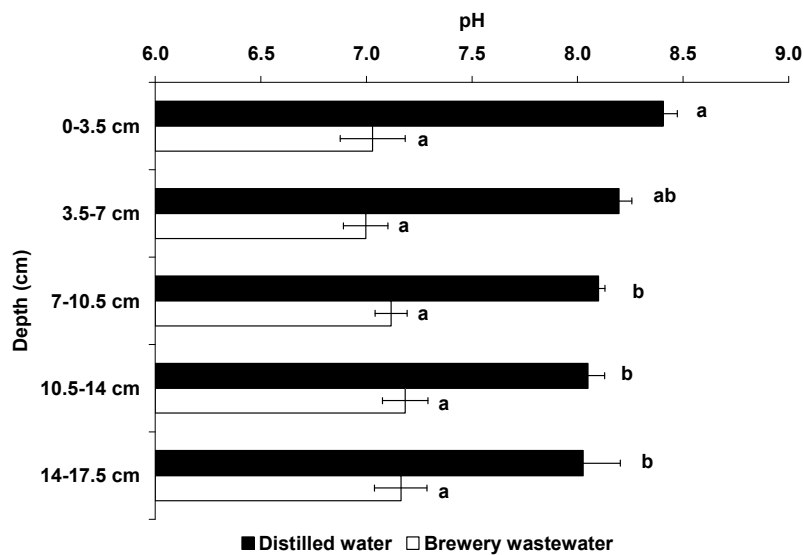


Figure 2. Variation of pH in the soil profile

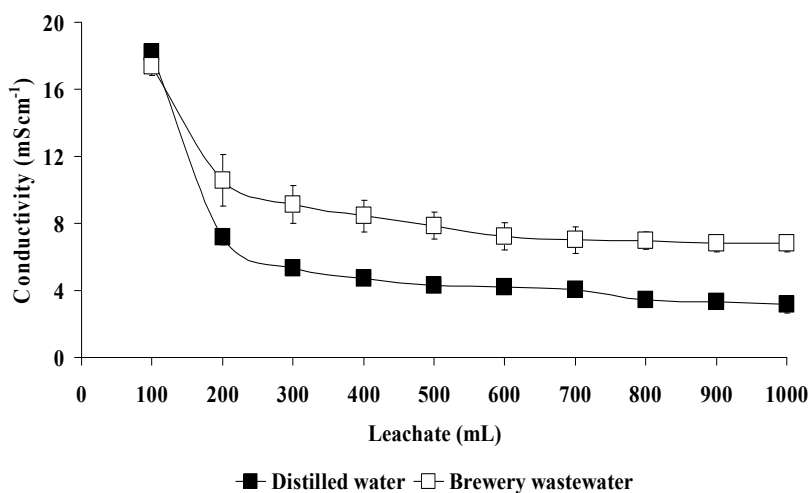


Figure 3. Variation of the conductivity in soil leachates.

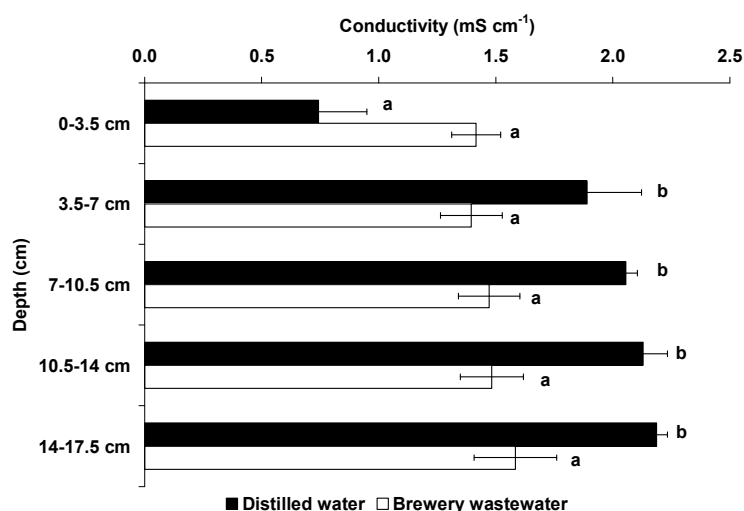


Figure 4. Variation of the conductivity in the soil profile.

The variation of conductivity in the soil profile is shown in the Figure 4. The irrigation with distilled water caused a decrease in conductivity at the 0-3.5 cm depth and an increase at the next depth. This behavior may be related to a displacement of salts from the first profile (0-3.5 cm) to the second profile (3.5-7 cm). In the case of brewery wastewater, salt mobilization was not observed; this is likely due to the addition of salt from the brewery wastewater. However, brewery wastewater irrigation causes a decrease in the conductivity of the soil. The application of distilled water and brewery wastewater has a similar effect on the conductivity and pH in the soil leachates but generates a different behavior in these variables in the soil profile. More studies about irrigation and the incorporation of organic matter are required in order to develop an appropriate procedure that allows the amelioration of soils in arid zones.

Conclusions

The irrigation with brewery wastewater improved the physicochemical characteristics of the Antofagasta soil. This is reflected by a decrease in the salt concentration due to leaching of the excess salts and by the stabilization of the soil pH produced by the incorporation of organic matter. Brewery wastewater may be used in the first step to improve the quality of saline soil where natural water is scarce, as is the case in the Antofagasta Region.

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