Land application of industrial effluent on a Chihuahuan Desert ecosystem: Impact on soil physical and hydraulic properties

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Project descriptors: industrial effluent, soil physics, Chihuahuan Desert

PROBLEM AND RESEARCH OBJECTIVES

Biological wastewater treatment technologies like land application can provide low-cost wastewater treatment in regions that can't afford expensive wastewater treatment infrastructure and in areas where wastewater discharge to surface waters is impractical. One of the major objectives of land application wastewater treatment systems is to allow the physical, chemical and biological properties of the soil-plant system to assimilate wastewater constituents without adversely affecting beneficial soil properties that control the transformation, transport, storage, and release of nutrients and contaminants into the wider environment (Magesan, 2001). Little data are available on the use of native terrestrial ecosystems for wastewater treatment, especially in arid and semi-arid regions of the southwestern U.S. and Mexico. Further, little is known about the impacts of wastewater irrigation on soil physical properties in native terrestrial ecosystems, and whether changes in soil chemical properties alter soil physical properties and plant growth.

Overall objectives of the proposed research are to expand knowledge of West Mesa soil chemical properties to include physical and hydraulic properties to schedule effluent irrigation more effectively. The specific objectives of this study were to (1) assess changes in chemical and physical properties of Chihuahuan Desert soils after 4 years of irrigation with secondary industrial effluent, (2) compare soil chemical and physical properties at three different sites (i.e., bareground, creosote, and mesquite) in irrigated as well as unirrigated areas, and (3) assess sprinkler distribution uniformity. A hypothesis for this study was that higher Ks beneath creosote and mesquite shrubs would contribute to deeper leaching of wastewater constituents compared to bareground areas.

METHODOLOGY

Sprinkler distribution uniformity assessment was carried out in the irrigated plot, following the American Society of Agricultural Engineers standard #S330.1 (ASAE Standards, 1993). Sprinkler heads (Senninger model #3012-1-3/4) installed on irrigation lines were placed on a 12 x 12 m grid. Within the 4-point spacing, 63 catch funnel collectors (0.19 m in diameter) were placed on a square grid at 1.5 m intervals. Outside, 7 catch funnels were placed underneath each of the 5 creosote shrubs to determine whether effluent precipitation underneath shrubs was higher than precipitation on bareground areas.

Bulk soil samples were collected along the drip line of creosote and mesquite shrubs, and in bareground areas between shrub canopies. There were 3 replications per site (i.e. creosote, mesquite, and bareground) in each plot. At each sampling site, samples were taken at 0-15, 15-30, 30-60, 60-90, 90-120, 120-150, 150-180, and 180-210 cm with a metal auger. For each replicate in the irrigated plot, soil samples were collected on north and south sides of shrub canopies, and at two bareground sites, for a total of 144 samples per year. For each replicate in the control plot, samples were collected only on the south side of shrub canopies, and at one bareground site, for a total of 72 soil samples per year.

Soil collected from each depth was air dried, mixed thoroughly and passed through a 2 mm sieve. Soil pH was measured in the saturated paste extract and concentrations of Na+, Ca2+, and Mg2+ used to calculate SAR, and ESP were measured by the solution conductivity method (USDA Staff, 1954). Chloride was measured by the colorimetric method (USEPA, 1979). Soil particle size analysis for determining sand, silt, and clay content was performed by the hydrometer method (Gee and Bauder, 1986).

Intact soil cores were taken at vegetated and non-vegetated sites at the depths of 5-10 and 25-30 cm. All cores were trimmed and the soil bulk density (pb) was obtained by the core method (Blake and Hartge, 1986). All cores were immediately saturated in tap water by slowly raising the water level. Saturated hydraulic conductivity (Ks) was determined by the constant head method (Klute and Dirksen, 1986). Volumetric moisture content (θ) of each soil core was measured at 0 kPa (saturation), 3 kPa, and 6 kPa suctions using a tension table (Leamer and Shaw 1941), and at 30 kPa, 100 kPa, 300 kPa, 500 kPa, 1000 kPa and 1500 kPa suctions (h) using a pressure plate apparatus (Klute, 1986). The θ at 1000 kPa and 1500 kPa suctions were determined on bulk soil samples <2mm in diameter. The difference in θ at 0 kPa and 6 kPa was calculated to estimate drainable porosity (θd), or soil macroporosity, the difference in θat 0 kPa and 30 kPa was used to estimate effective porosity (θe), and the difference in θ at 30 kPa (Field capacity; FC) and 1500 kPa (Wilting point; WP) was used to estimate plant available water capacity (AWC). Brooks and Corey (1964) model was fitted to the measured h(θ) curves to obtain the air entry value ($1/\alpha$) and the pore size distribution parameter (λ) by using the retention curve (RETC) program of van Genuchten et al. (1991).

FINDINGS AND SIGNIFICANCE

Soil texture and bulk density (pb) did not differ between irrigated and control plots, but did so between bareground and mesquite sites in the control and irrigated plots. Reductions in saturated hydraulic conductivity (Ks), drainable porosity (θd,) and effective porosity (θe) in the upper 0-15 cm of irrigated plot soils were attributed to decline of soil structure and dispersion of clays resulting from the addition of highly sodic and alkaline effluent to irrigated plot. Although rarely significant, consistently higher electrical conductivity, sodium adsorption ratio, chloride, exchangeable sodium percentage, and Na+ in the soil profile (between 30 cm and 210 cm) at creosote and mesquite sites compared to the bareground site suggested deeper leaching of wastewater constituents at shrub sites. Deeper leaching of wastewater constituents beneath shrubs compared to bareground areas may be attributed to higher water inputs caused by sprinkler spray interception, and higher Ks, θd, and θe of soils beneath creosote and mesquite canopies.

Low sprinkler distribution uniformity (53.7%) within a 4-point spacing in the irrigated plot was observed. Low sprinkler uniformity, and low sample size were possible reasons for few statistical differences detected for chemical properties among vegetated sites. High strength industrial effluent applied to the sandy loam Chihuahuan Desert soils caused sodic conditions (SAR > 25 and pH > 8.5) in the upper 60 cm of irrigated plot soils, which threatens the survival of herbaceous and woody plant species living in this ecosystem. Sprinkler precipitation underneath creosote shrubs located near the sprinkler heads was higher than in bareground areas. Continued application of industrial effluent to a Chihuahuan Desert ecosystem over the long term should consider the relative importance of canopy and intercanopy areas.

The current study was carried out at two plots one of them was irrigated with effluent water and the other was controlled or unirrigated. Both these plots were located on bluepoint loamy sand. The examination of soil map from shows that in addition to blue point, another soils, Onite-Pajerto association, is also present in the study area. Therefore, additional soil samples will be collected from this area and soil physical, chemical properties and sprinkler uniformity will be assessed. Since sprinkler uniformity is low in the study area, more uniformity tests will be conducted to better understand the influence of wastewater application on soil properties. More surface soil samples will be collected in early 2009 on a spatial scale to carry out a geospatial analysis of soil properties and sprinkler uniformity data. The soil water content and other meteorological data are collected from the study area, all these data will be used to model the variations in soil moisture content and soil water fluxes from bareground and canopy sites using rootzone water quality and hydrus model