

POTENTIAL HAZARD DERIVED FROM WASTEWATER REUSE WITHIN THE RECLAMATION STRATEGY OF A TECHNOSOL

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Abstract

Wastewater applied to soil eventually re-enters the water cycle by percolating to groundwater, or evaporating from soil and plants into the atmosphere. The ability to predict the transport of hazardous chemicals in soils and subsoils is key for the correct management of wastewater. The movement of solutes through the soil is complex and involves hydrological, physical and chemical characteristics of both soil and influent solution. The application of organic matter from wastes could represent an alternative for improving soil quality but it also has the potential to modify soil-water interactions. For this reason, infiltration tests were conducted to evaluate water movement and solute transport using synthetic wastewater on a technosol originated from an iron mine dump. In addition, the effect of added compost to soil for improving soil quality was also evaluated. Irrigation with wastewater of the studied technosol poses a risk to groundwater due to leaching of NO₃⁻ and OC but not for PO₄³⁻.

Keywords: organic carbon, technosol, infiltration, wastewater.

Introduction

The production and disposal of wastewater (WW) has increased sharply as a result of population growth and water demand. Its production results from numerous activities, therefore WW characteristics are related with its origin. Wastewater contains many substances, including dissolved and suspended compounds, such as organic carbon (OC), nutrients (N and P), surfactants, solids and microorganisms, some of them harmful for the environment and dangerous for human health. Wastewater treatment systems were designed to minimize the environmental impacts of untreated discharges. However, the degree or treatment adopted depends on characteristics of wastewater and on the quality of the effluent send back after treatment. In spite of WW treatment, reuse of WW with minor or no treatment also represents an alternative when the buffering soil capacity is adequate. Among the substances within WW, dissolved organic carbon (DOC) is considered the most mobile and reactive fraction, controlling a number of physical, chemical and biological processes in both aquatic and terrestrial environments. At the same time, soils with low OC content, such as those from degraded areas made up from wastes during mining activities, could benefit from the addition of organic

substances. In fact, sewage sludge is currently used as an organic amendment due to its high content of organic matter and nutrients for reclamation of degraded zones by mining activities; representing an economical and practical way of waste disposal. Before application to soil, the sludge has to be stabilized to prevent an unacceptable accumulation of pollutants, bad odours and the risk of diseases from microbes. Therefore the objective of this work is to evaluate the capacity of a technosol developed from an iron mine dump, with and without compost addition, to buffer WW components after irrigation with WW containing high OC load.

Material and Methods

Substrates and Influent

The studied area is an iron mine dump planned to be used for residential, leisure and agro-industrial activities. The soil is a degraded technosol with high infiltration rate under a continental Mediterranean type of climate. Mean annual precipitation amounts to 357 mm and it is evenly distributed, mainly concentrated during autumn and winter. Summers are extremely dry; consequently irrigation will be needed to preserve premature vegetation senescence during the absence of rain.

As an alternative for improving soil quality, compost (C) from a mix of sewage sludge and vegetable wastes was added at 10% (w/w). Before addition, compost was homogenized and sieved (< 2 mm). Three influents were used for infiltration experiments: tap water (TW) and two synthetic wastewaters (SW1 and SW2) containing usual components from domestic wastes (Table 1) at concentration above local wastewater (Granada, Spain).

Table 1. Main properties of the substrates and influent

		WW1	WW2		Compost	Technosol
pH		6.0	5.9		6.8	8.1
EC	dS m ⁻¹	0.77	1.64	dS m ⁻¹	1.6	0.06
OC	mg L ⁻¹	224	560	mg kg ⁻¹	150	2.3
NO ₃ ⁻	mg L ⁻¹	140	350	mg kg	5.3	38.7
PO ₄ ³⁻	mg L ⁻¹	140	350	mg kg	41	14.7
Na	mg L ⁻¹	39	65		no	no
SDBS	mg L ⁻¹	40	100		no	no

WW: wastewater; EC: electrical conductivity; OC: organic carbon

Infiltration Experiments

Column experiments were conducted according to Mingorance et al. (2007) using polypropylene tubes, 2.5 cm internal diameter and 20 cm long. The air-dried soil (< 2 mm) was packed to

a height of 10 cm and infiltration experiments started from unsaturated conditions at air-dried soil water content. Input solutions from a Boyle–Marriot bottle at 2 cm constant-head boundary conditions above the soil surface were maintained throughout the experiments. Infiltration was continuously monitored and drainage at the bottom of the soil column was also collected for analysis at different times. Effluents were characterised: pH, EC, DOC, nitrates, phosphates and Na. Infiltration characteristics were described by mean of the saturated hydraulic conductivity (K_s) and sorptivity (S), computed by fitting the data to the Philip's infiltration model (1957). Saturation time (T_s), total infiltration (I_t) and saturated water content (Θ_s) for each soil columns was calculated from its corresponding infiltration curve. Analysis of infiltration raw data, as well as the fitting to the infiltration model, was carried out by a program written in R language (R Development Core Team, 2008) following the procedure described in Mingorance et al. (2007).

Results and Discussion

Prior to infiltration tests, preliminary information on soil and influent solutions were gathered as show Table 1. Downward infiltration into an initially unsaturated soil occurs under the combined influence of suction and gravity gradients. At the beginning of the infiltration process the suction gradient is dominant and as the water penetrates into the soil the suction gradient decreases and the gravitational gradient becomes the main driving force moving the water downward, with the water flux approaching the saturated hydraulic conductivity as a limiting value. Cumulative infiltration curves for both amended and natural soil irrigated with WW1 are shown in Figure 1. Both sorptivity and K_s increased up to twice in compost amended soil ($44 \text{ mm h}^{-1/2}$ and 4 mm h^{-1} , respectively); T_s tends to increase when compost is added showing a different influence of WW compared to TW; I_t showed a strongly reduction after WW infiltration on compost amended soil.



Figure 1. Cumulative infiltration curve for original soil and soil+compost irrigated with WW1.

Changes on lixivate chemical properties after irrigation were measured to elucidate potential release of solutes when soil interacts with irrigation water of different quality. As it is known,

concentration of suspended materials in the drainage water, mainly the amount of organic matter and electrolyte contents, depend on the soil-water retention and transmission characteristics.

Both compost and WW irrigation increase OC and NO_3^- concentration in the leachate. However, the presence of compost produces a larger increase in chemicals concentrations compared to natural soil irrigated with WW. Compost amended soil irrigated with WW reduces drainage of chemicals compared to tap water application. Despite the phosphate (PO_4^{3-}) content in WW, it is not detected in leachate. Therefore, PO_4^{3-} presents in WW could be fixed by chemically binding from soil minerals such as calcium (10.8%), and iron (23.8% as oxides) (Monterroso et al., 1996). There were no significant changes in leachate pH, conversely electric conductivity increases with the addition of compost to the soil.

Conclusions

Preliminary results allow us to conclude that reuse of WW during the reclamation process of the studied technosol poses a risk to groundwater due to leaching of NO_3^- and OC, particularly when the soil was amended with compost. Nevertheless, soil characteristics are prone to retain phosphate, acting as a natural filter. Special attention should be place when soil reclamation practices include addition of ameliorants.

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