Journal of Environmental Management 217 (2018) 718–726

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Assessing the effect of industrial wastewater on soil properties and physiological and nutritional responses of *Robinia pseudoacacia*, *Cercis siliquastrum* and *Caesalpinia gilliesii* seedlings

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ARTICLE INFO

Article history:
Received 28 November 2017
Received in revised form
14 March 2018
Accepted 20 March 2018
Available online 24 April 2018

Keywords:
Plant physiological characteristics
Wastewater
Environmental pollution
Macronutrients

ABSTRACT

The main aim of this study is to investigate the physical and chemical properties, including soil salinity, acidity, concentrations of macro-nutrients (phosphorus, potassium, and Calcium-Magnesium) and sodium adsorption ratio to the soil, physiological and nutritional traits of three plant species including *Caesalpinia gilliesii*, *Robinia pseudoacacia*, and *Cercis siliquastrum*. First, some sample were taken from the agricultural soils irrigated with wastewater. The results of initial soil test revealed that the irrigation with wastewater significantly increased sodium adsorption ratio (SAR), electrical conductivity (ECe), cation exchange capacity (CEC) of the soil ($p < 0.05$). Secondly, the effect of industrial wastewater on the responses of three plants were investigated. According to the results, the highest shoot fresh weight was observed in *C. gilliesii* seedlings treated with T100%, which is 35% higher than the control treatment. The highest concentration of shoot phosphorus in the three plants was respectively 0.54, 0.72, and 1% in those treated with T100% and 0.41, 0.48, and 0.83% in the control treatment. The amount of shoot potassium in the three plants treated with $T_{100\%}$ was respectively 0.84, 0.48, and 1%, while it was 0.43, 0.4, and 0.1 in the control treatment, respectively ($p < 0.05$). According to the current concerns about increased EC, SAR, and Na in *C. gilliesii* treated with $T_{100\%}$, as compared to the control treatment (50, 386, and 412), and the positive effects of wastewater on soil properties (CEC, pH, and K) and morpho-physiological responses of the plant, it is recommended to use wastewater with continuous monitoring to prevent the pollution of water and soil resource.

1. Introduction

Limited freshwater resources are a serious problem in many countries (Babran and Honarbakhsh, 2008). The use of wastewater is a common approach to drought management in agriculture. Today, about 80% of wastewater is used for effective irrigation in 70–80% of food safety (Moussavi et al., 2013; Mara and Cairncross, 1989). Accordingly, it seems that the use of wastewater for irrigation, in addition to water supply, can be an appropriate choice. So it can lead to saving part of the costs for the administration of chemical fertilizers. Sometimes irrigation with wastewater is more efficient than the use of normal water (Jenkins and Russell, 1994). Many scholars have studied the effects of wastewater application on plants and soils. Studies on *Malabar spinach* irrigated with treated wastewater led to economic growth as compared with plants irrigated with underground fresh water (Bhuiyan Rahman et al., 2016). However, the use of wastewater can damage the environment depending on the amount and the composition of the wastewater and soil sensitivity to the change (Al-Nakshabandi et al., 1997; Falkiner and Smith, 1997; Bond, 1998). For irrigation purposes, water quality is usually classified according to its electrical conductivity (EC) and sodium adsorption ratio (SAR). In addition, soil texture, rainfall, and crop resistance should be considered in the evaluation of the potential of wastewater (Singh, 1996). In general, a high value of SAR ($SAR > 9$) has negative effects on the soil quality, particularly for soils with low electrical

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https://doi.org/10.1016/j.jenvman.2018.03.087

conductivity (EC < 1 dS/m) (Hamilton et al., 2007). Treated wastewater can change the physical and chemical properties of the soil. According to Yintao et al., 2015(, a 20-year long-term use of treated wastewater may increase heavy metals and may reduce the acidity of agricultural soils. Blum et al. (2012) stated that the irrigation with wastewater destroyed the soil structure and changed the properties of soil. Entering the wastewater into the agricultural lands is a great problem. Wastewater has been introduced as a resource for providing irrigation water, which is very important in arid regions. Barrow et al. (1997) reported that in arid areas, industrial wastewater is used for irrigation. On the other hand, due to its nutrient contents, wastewater can enhance the crop yield. Due to the high levels of nutrients such as N, P, and K, wastewater can provide plants with useful nutrition, as a result increase crop yield (Nazari et al., 2006). Due to lack of water and the need to develop green spaces, natural resources, and agriculture, this study was aimed at investigating the effects of wastewater on the soil physico-chemical properties and morpho-physiological responses of three plant species.

2. Methods

2.1. Sites

The study covers an area of 108 ha and 151 industrial units between 35° 27′ N and 36° 45′ N and 48° 45′ E and 48° 45′ E. The altitude is 1277 m above sea level. The average minimum and maximum temperatures are 7.2 and 21.7 °C, respectively. Furthermore, 321.5 mm average annual rainfall was reported. Due to the release of industrial wastes into the area, the dominant plants are *S. maritimus* and *P. australis* (Mohammadi et al., 2011). This study was conducted during 2014–2016 to evaluate the effects of refinery effluent of Alborz Industrial City (Iran) on the growth of three plant species including *Robinia pseudoacacia*, *Cercis siliquastrum*, and *Caesalpinia gilliesii*.

2.2. Sampling design

We designed the experiment to compare morpho-physiological characteristics of three plants under different treatments (3 replication × 3 plants × 4 treatments = 36 pots total). Soil sampling from the area was conducted according to systematic – randomized sampling method from the lands irrigated with wastewater, and control samples were taken from the lands irrigated with clean water. All samples were taken from the depth of active root (0–15 cm) and were put into polyethylene plastic bags. Samples (four soil samples contaminated with wastewater in various sites) were taken for analysis and they were then air-dried. The soil samples were sieved (4 mm) and then the physical and chemical properties were determined. Physiochemical properties of the soil before and after irrigation with the wastewater, including pH, EC, CEC, SAR, Na, and macronutrient elements (P, K, and Ca-Mg) (Table 1) were determined using standard methods (Sparks, 1996). Treatments consisted of four levels of wastewater including $T_{100\%}$ (100% wastewater); 50% (50% wastewater$_+$50% distilled water); 25% (25% wastewater$_+$75% distilled water) and 0% (distilled water as a control) and three plant species with three replications.

2.3. Greenhouse cultivation

Greenhouse cultivation of the plants was done to evaluate morpho-physiological characteristics of R.pseudoacacia, C. gilliesii, and C. siliquastrum under different treatments of Alborz Industrial City wastewater. For this purpose, almost uniform seedlings were transferred to the greenhouse for planting. Greenhouses temperatures (day/night) were 25 ± 5/17 ± 5 °C, with a relative humidity of 60% and natural sunlight. The weight of soil in each pot was 4500 g and irrigation of the pots was carried out in weights by measuring the moisture content and the pot on the scale. The amount of water needed was irrigated with distilled water and the moisture content was applied according to the moisture level of the farm capacity.

At the end of the seven months' growth period, the plants were harvested separately, 1 cm distance from the surface soil and then different parameters including fresh and dry weights (using digital weightier with 0.001 accuracy), leaf area (CI-202 Area Meter), chlorophyll (SCMR way by using SPAD-502 (Minolta, japan), macronutrient elements such as P (Olsen and Sommers, 1982)and the chemical characteristics of the wastewater according to standard methods (Moradinasab and Behzad, 2016; Ramirez-Fuentes et al., 2002) were measured.

2.4. Soil and plant physico-chemical characteristics

Soil texture and field capacity were measured using hydrometer and pressure chamber methods, respectively. The chemical properties of the soil (according to the purpose and type of the research) pH (using a pH meter) electrical conductivity (EC meter) CEC according to (Loeppert and Inskeep, 1996) potassium (using flame photometer), available phosphorus using spectrophotometer Schimadzo uv-3100 (Olsen and Sommers, 1982) were measured. Organic matter (following wet oxidation method) and total nitrogen (based on colorimetric titration) were measured using Kjeldahl's method. SAR of the soil samples was determined by titration of EDTA solution to determine the concentration of calcium and total calcium and magnesium in the soil saturation extract. The concentration of sodium and potassium was measured by a flame photometric method (ELEA model). Also, the amounts of calcium and magnesium concentrations were determined by titration with EDTA (Klute, 1986). For the industrial wastewater chemical properties, parameters like pH, electrical conductivity (EC), and nutrients such as potassium and phosphorus were determined.

2.5. Data analyses

Data were analyzed following a factorial completely randomized design. Firstly, data were normalized (Kolmogorov–Smirnov test). In order to assess the existence or absence of difference between concentrations of heavy metals in the soil and plant species, one-way analysis of variance was performed. To compare the concentrations obtained for the soil and plant species with normal values, T – test was used. The data were analyzed using SPSS and mean

Table 1
Mean ± SD Values for characteristics of the soil before irrigation with wastewater.

Sample /parameter	Soil texture	pH	EC[a] (dS/m)	SAR[b]	CEC[c] (Cmolc/kg)	Ca-Mg (meq/l)	Na (meq/l)
	Clay Loam	3.14 ± 7.0	2.1 ± 12.74	11.6 ± 03.87	24.0 ± 35.75	3.8 ± 28.3	13.7 ± 3.77

[a] (Electrical Conductivity).
[b] (Cation Exchange Capacity).
[c] (Sodium Adsorption Ratio).