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Assessment of the effect of landfill leachate irrigation of different doses on wheat plant growth and harvest index: A laboratory simulation study

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ABSTRACT

The aim of this study was to assess the suitability of landfill leachate irrigation for wheat plant (*Triticum aestivum*) by evaluating the trace element accumulation, plant growth (shoot length, root length, number of leaves), and harvest index at different leachate dose rate soil. For the laboratory simulated irrigation, leachate sample was collected from the Ghazipur landfill site, Delhi which has an area of 30 ha and a dumping quantity of 2800 tons per day (TPD) of solid waste. The three treatment groups: control soil (C), fertilizer treated soil (C-F) and leachate treated soil with different concentration: C-L1 (50 ml), C-L2 (150 ml), C-L3 (300 ml), C-L4 (450 ml) and C-L5 (600 ml) were used for this experiment to assess the wheat plant growth under various treatments. Leachate irrigation on soil modified the physicochemical properties of soil by increasing the pH, EC (electrical conductivity), organic content, exchangeable nutrients, available phosphorous (Avail. PO_4), total nitrogen (TN) and trace elements. Trace elements concentrations in soil and wheat grain were below the Indian permissible limit under various treatments. Growth parameters of wheat plant showed positive response at all leachate dose rate soil and fertilizer treated soil as compared to control soil. The highest harvest index (HI) found in 450 ml leachate dose rate soil (C-L4) due to higher number of grains suggests that leachate can be used as fertilizer. In order to estimate the potential health risk from trace elements by consuming wheat grain, hazard quotient and hazard index have been calculated. It has been observed that trace element risk was not noticeable except 600 ml leachate irrigated soil (C-L5). The study recommends that the optimum dose of leachate can be used as a fertilizer.

1. Introduction

Sudden rise in the quantum of municipal solid waste (MSW) has been felt and it is mainly due to increase in disorganized industrialization and urbanization which is a resultant of uncontrolled population growth (Singh et al., 2011; Singh et al., 2015a).Use of landfills is a common practice for disposal of MSW; however, due to improper engineering measures and facilities these landfills act as a prominent source for polluting the soil and water bodies (Singh et al., 2015b).The leachate generated from the landfill, mixed with rain water pollutes soil and groundwater, thereby potentially impacting aquatic ecosystems and human health (Harrington and Maris, 1986). Safe disposal of the MSW is one of the major environmental concerns in developing countries. Landfilling and land application of MSW and leachate are recommended to be the most cost-effective and convenient options of MSW disposal. Municipal solid waste leachate considered as a source of nutrients and water and used as fertilizer (Romero et al., 2013). Land application of landfill leachate increased the quantity of macro- and micronutrients in the soil and in turn improved the soil productivity and crop yield (Khoshgoftarmanesh and Kalbasi, 2002). Leachate contains high strength of ammonium nitrogen in the range of 2000–5000 mg/l in the Hong-Kong landfill site which can be used to produce fertilizer (Li and Zhao, 2003).

The leachate generated from the municipal landfills is highly viscous and concentrated liquid having constituents dissolved organic matters, inorganic compounds such as Ca, Mg, K, NH_4, Fe, SO_4 etc. (Williamson, 2001) is beneficial for plant growth and development (Singh and Agrawal, 2010). Due to Industrial waste dumping, leachate may also contain high levels of toxic trace elements such as cadmium, chromium, copper, lead, nickel, zinc etc. (Lee and Jones-Lee, 1993; Christensen et al., 2001; Tengrui et al., 2007; Ogundiran and Afolabi, 2008). Further, numerous organisms like viruses and bacteria, immiscible liquids and suspended solids (small particulates) may also present in leachate.

Municipal waste leachate can be used as a liquid fertilizer mainly in calcareous soils due to high amount of organic matter and plant

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nutrients. Since leachate is highly saline in nature, hence, its frequent application as well as high dose is not recommended to saline-sensitive crops (Khoshgoftarmanesh and Kalbasi, 2002). Application of MSW leachate on soil affects the physical and chemical properties of soil. Leachate application on plants imposes both positive and negative impacts on the growth of plant as was observed by Cheng and Chu (2007). Leaf impairment, decrease in crop yield, premature senescence and poor plant survival are the probable effects of leachate irrigation on plant (Menser et al., 1983). An increase in the growth of *Salix babylonica, Phalaris arundinacea,* and *Populous nigra* can be seen on application of leachate but some symptoms of phytotoxicity, like necrotic spots and brown leaves were witnessed in leaves, while willows had shown degradation of chlorophyll and chlorosis (Cureton et al., 1991). Diluted leachate when irrigated on *Acacia confusa, Leucaena leuocephala* and *Eucalyptus torelliana* showed a positive response in their growth and stomatal conductance (Liang et al., 1999). Khoshgoftarmanesh and Kalbasi (2002) have suggested the dose of leachate for the rice plant based on heavy metal and other pollutant concentrations in Iran. No such recommended standard dose or guideline is available in India

The objective of the present investigation was to deduce the effect of leachate application on soil and wheat plant growth along with the assessment of non-carcinogenic risk of wheat grain consumption. There are no reports available on response of wheat plant grown at various dose of leachate.

2. Material and methods

2.1. Experimental design

The experiment was conducted at the Yamuna hostel garden of Jawaharlal Nehru university, New Delhi, India, between November 2013 and March 2014. The seven pots were divided into three treatment groups: (1) control soil (C); (2) water with fertilizer added (C-F) (3) and diluted leachate with different concentration: C-L1 (50 ml), C-L2 (150 ml), C-L3 (300 ml), C-L4 (450 ml) and C-L5 (600 ml). Scatter the wheat seeds in the equal amount in each earthen pot, containing homogenously mixed soil. Wheat seed is covered by the soil to avoid the seed from drying. In spring season, seeds plant it 1.5 in. deep while in winter season should be 2.5 inches. Irrigation with water only (tap water) was included as a control soil (C). The fertilizer group (C-F) was treated with the DAP-Urea-Potash fertilizer. DAP and potash fertilizer used at the time of seed scattering while urea fertilizer were applied at 21 days after sowing (DAS). In order to provide nitrogen to soil, urea is most conveniently used fertilizer. Application of fertilizer will make the wheat grow faster and absorb all the moisture in the ground. Diluted leachates with different concentrations were applied half at 10 days and half at 30 days after sowing (DAS). There were three replicate pots of each treatment. Only 3 times tap water is applied during the irrigation experiment to maintain moisture in the soil.

2.2. Leachate analysis

Leachate sample was collected from the Ghazipur landfill site, Delhi which has an area of 30 ha and a dumping quantity of 2800 ton per day (TPD) of solid waste. The sample was stored in airtight polyethylene bottles and transported to the laboratory for chemical analysis. The pH and EC (electrical conductivity) were estimated on site at the time of sampling with pH and EC meter, respectively. Calcium (Ca) was estimated by titrimetric method (APHA, 2005) while magnesium (Mg) was estimated by the atomic absorption spectroscopy. The sodium (Na) and potassium (K) concentrations were determined by flame photometric method while UV–vis spectrophotometer was used for analysis of total kjeldahl nitrogen (TKN) and phosphate (PO_4^{3-}) (APHA, 1995). Open reflux digestion method and azide modification of Winkler method were used for analysis of chemical oxygen demand (COD) and biological oxygen demand (BOD) respectively (APHA, 2005). The trace element concentrations (Fe, Zn, Cu, Cd, Cr, Pb, Mn and Ni) were determined by atomic absorption spectroscopy (AAS). For the trace element analysis, 50 ml of leachate samples are digested with 10 ml of conc. HNO_3 at 80° C until the solution become transparent (APHA, 2005). After then the solution was filtered through whatman filter paper and diluted to 50 ml with distilled water.

2.3. Soil analysis

A monolith of 10 cm × 20cm × 30 cm in each pot was taken before plantation and after mowing the wheat plant for collection of soil samples. Soil samples were dried by air for 15 days and were filtered through 2 mm seive before taking up the analysis. pH of soil was measured by using glass electrode pH meter (EUTECH instruments) by forming 1:5 soil-to-water solutions, stirred for 2 h and standardized with pH 4, 7 and 9.2. Conductivity electrode was used to measure EC of the soil samples from saturation extract (IARI, 2011). Jackson (1958) had explained the ammonium acetate methodology for estimation of exchangeable sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) in soil. Soil samples mixed in Ammonium Acetate solution were shaken thoroughly for 2 h and thereafter for settling the soil particles left for overnight and then filtered. After then, flame photometer (Elco CL-378) and atomic absorption Spectrophotometer (M series AAS, Thermo scientific, Cambridge, UK) were used to estimate the exchangeable cations from the filtered solution. Organic contents (Organic C) in the soil samples were estimated with the help of Walkley and Black's rapid titration method (Allison, 1973). Olsen and Sommers (1982) method of $NaHCO_3$ extraction was used to quantify the available phosphorous (Avail. PO_4) in the soil samples by using UV–3200 double beam spectrophotometer. Kjeldahl method was used to determine the total nitrogen content (TN) of the soil. Trace elements content of soil sample was estimated with the help of tri acid mixture. 1 g (gram) of soil sample was taken and digested with the 20 ml of tri acid mixture (HNO_3:H_2SO_4:$HClO_4$:5:1:1) for a duration of 8 h at 80 °C (Allen et al., 1986). Subsequent upon complete digestion, the solution was got filtered by using the whatman filter paper and the filtrate was examined for trace element. Trace element concentration was analyzed by using Atomic absorption spectrophotometer. In order to minimize the chance of error a calibration was implemented at interval of every 10 sets of samples with help of prepared internal standards (i.e. standards curve approach). All the due attention was observed while preparing and examining samples to reduce the glassware, and reagents contamination. Use of only double-distilled water was ensured during the complete study.

2.4. Growth parameters and trace elements analysis in plant

Eight plants were selected randomly before harvesting from each treatment for growth analysis, harvest index and trace element accumulation. For growth analysis, plants were analyzed for number of leaves, root length and shoot length at the time of 50 and 90 days. The fresh weight of each plant part was measured and thereafter dried for 48 h at 70 °C. The calculation of ratio of weight of grains/plant to the biomass above the ground indicates the harvest index (HI). For the trace element analysis, plant tissues were collected and rinsed with tap water and distilled water, after then separated into different plant parts like leaf, stem root and grains. Dried plant parts were converted into powdered form by stainless steel blender and then passed through a sieve of 2 mm mesh size. 1 g of powdered sample was digested in 20 ml tri acid mixture (HNO_3:H_2SO_4:$HClO_4$:5:1:1) till then transparent colour appeared (Allen et al., 1986). After digestion the solution was filtered and filtered solution were used for trace element analysis by using atomic absorption spectrometer. Wheat plants were finally harvested after four an half months.

Soil and plant data were subjected to one-way analysis of variance (ANOVA) using sigma plot 11.0. ANOVA is used to determine the