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Runoff and sediment behavior from soil plots contaminated with kerosene and gasoil

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ABSTRACT

Although impacts of several hazardous inputs on the environment have been widely investigated, the role of petroleum contaminations on hydrological behavior of soil has not been sufficiently addressed. Changes in hydrological behavior of contaminated soil generally exert an important influence on the relationship between the infiltration process and runoff generation, causing several environmental threats. This study aimed to investigate the effect of different petroleum levels on runoff generation and sediment yield under simulated natural conditions. Consequently, three levels of Kerosene and Gasoil (0, 130 and 2600 g m^{-2}), and two slopes (5% and 25%) were applied each with three replicates to experimental soil plots. A well-equipped experimental setup was designed and conducted in the rainfall and soil erosion simulation laboratory with a constant 35 mm h^{-1} rainfall intensity for 30 min. The corresponding flow behavior of plots to governing conditions was continuously monitored and analyzed. Results indicated that both runoff and sediment yield were significantly ($p < 0.05$) influenced by different types of contaminants. Increasing oil concentrations had maximum impact on the studied variable particularly when the slope was set to5%.Maximumdecrease and increase rates in time to runoff and runoff coefficient were found for 2600 g m^{-2} Gasoil for a slope of 5%. Comparing the variations in runoff volume and sediment concentration during the rainfall events indicated an obvious difference between these two variables. The runoff volume increased with time, while sediment concentration first reached a peak value and started decreasing afterwards. Gasoil-contaminated soils yielded much larger runoff and sediment compared to that of Kerosene-contaminated soils. The effect of slope on sediment generation was stronger in contaminated soils than in uncontaminated soils. Results further confirmed the significant effect of Gasoil or Kerosene on increasing soil loss due to decreasing infiltration and increasing water repellency. Increase in runoff volume and sediment generation with increasing oil concentration and slope urging the necessity of further considerations to control soil contamination for both soil and water conservation purposes.

1. Introduction

Several organic and inorganic contaminants are daily imposed to soils worldwide as a result of industrialization (Nouri et al., 2014; Davari et al., 2015a; Eskandari et al., 2015). In recent years, many soils have been contaminated by inorganic and organic wastes due to petroleum activities, mining, industrial emissions, sewage sludge applications and waste disposals (Asadi Kapourchal et al., 2011; Eskandari et al., 2012; Farrokhian Firouzi et al., 2015; Davari et al., 2015b). Most of these contaminants are generally concentrated in topsoils (Khodaverdiloo and Homaee, 2008; Atafar et al., 2010; Jafarnejadi et al., 2011, 2013) leading to widely different environmental problems and toxicities at different scales (Asadi Kapourchal et al., 2009; Babaeian et al., 2015).

With the overuse of petroleum compounds as an energy source, the petroleum contaminated soils occur often as a result of transportation, storage, use and accidental release of petroleum products (Wilson and Jones, 1993; Guerin et al., 2002; Zhang et al., 2014). In 2010, the US Environmental Protection Agency (US EPA) estimated that there were more than a half million federally-regulated leaking underground storage tanks (USTs) nationwide in the United States (USEPA, 2012). Soil contamination has become an increasing environmental problem, and the contaminants usually have adverse effects on soil and water quality. Among contaminants, petroleum compounds are a widespread class of environmental pollutants. When a petroleum spill occurs and the volume of release is high and continuous, it infiltrates the soil and reaches

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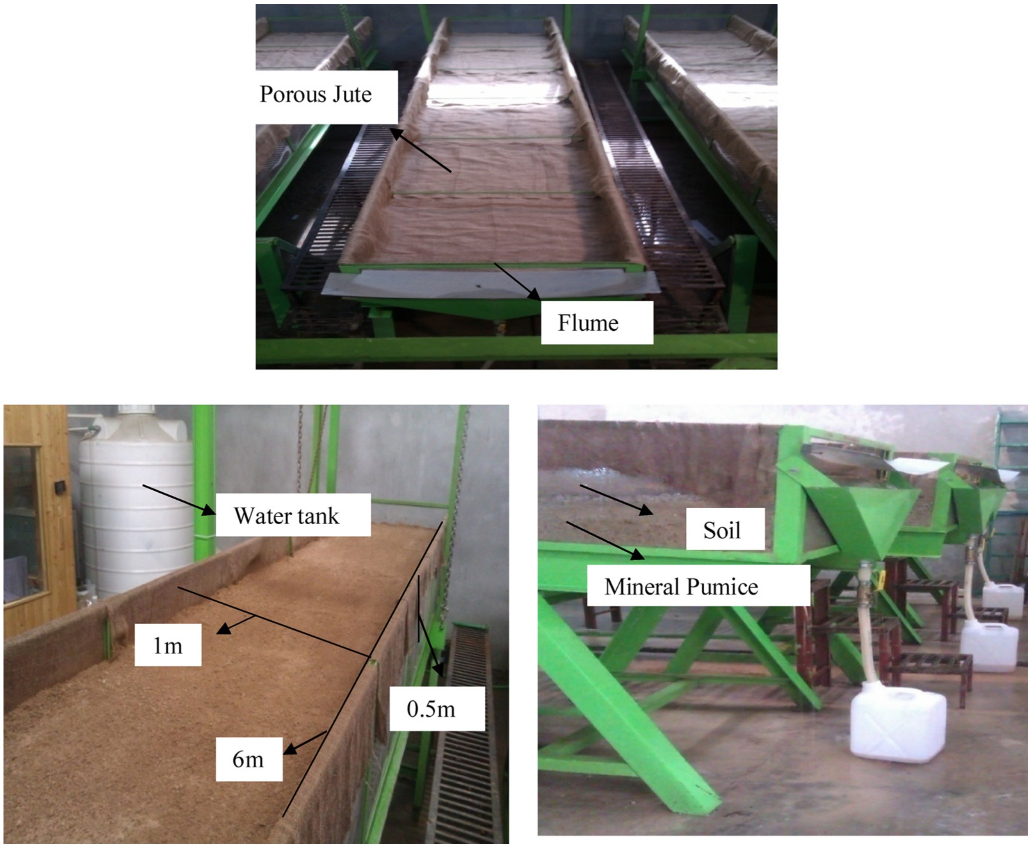

Fig. 1. A general view of the experimental set up including the plots and runoff collecting system.

Table 1
Some physical and chemical properties of the studied soil.

Organic matter (%)	pH	EC (ds m^{-1})	Particle density (g m^{-3})	Bulk density (g cm^{-3})	Total Porosity (%)	Clay (%)	Silt (%)	Sand (%)
1.20	7.80	0.67	2.60	1.30	0.50	30	50	20

Table 2
The experimental plot treatments and their abbreviations.

Treatments	Abbreviation
Control	C
Kerosene (130 g m^{-2})	K1
Kerosene (2600 g m^{-2})	K2
Gasoil (130 g m^{-2})	G1
Gasoil (2600 g m^{-2})	G2
Slope of 5%	S1
Slope of 25%	S2

the capillary fringe zone and eventually to the water table (Hunt et al., 1988). The percolation, dissolution, and equilibration of petroleum contaminants, particularly low viscosity and highly soluble petroleum products, threaten potable groundwater quality (USEPA, 2013). Furthermore, petroleum hydrocarbons can show potential mutagenic and carcinogenic effects on humans and pose very adverse impact on the environment (Nadim et al., 2000; Boehm et al., 2008).

Following release of different disposals to the environment, refined and residual petroleum products may accumulate in soils and sediments (Neff et al., 1994; Tolosa et al., 2004). The extent of contamination depends on the chemical composition of the contaminant and the properties of the soil (Fine et al., 1997). When a soil is contaminated with chemical compounds, some interactions may occur between the soil and chemicals which result in changing the physical properties of the soil (Meegoda and Rajapaksee, 1993). Information on environmental impacts, physicochemical properties and behaviors, and soil-contaminant relationships are necessary in order to remediate or utilize contaminated soils. These alternations of soil properties may disturb the movement of water in contaminated soils. Puri et al. (1994) studied water permeability through contaminated soils with three commercial grade motor oils. Their results showed that the coefficient of permeability decreased with the increase of the oil saturation and the viscosity of the oil. Retention capacity of oil contaminated soils was also investigated by Yong et al. (1994). The effect of crude oil pollution on soil properties was investigated by Ogboghodo et al. (2004) under a natural environment. Effects of petroleum pollution on clay soil microstructure were studied by Izdebska-Mucha and Trzcinski (2008). Rahman et al. (2010) investigated the effect of oil contamination on geotechnical properties of basaltic residual soil. Zhang et al. (2014) studied the impact of residual non-aqueous phase liquids (NAPL) on hydrodynamic properties of porous media. They indicated that contaminated soils had a slightly higher water retention capability than uncontaminated soils. Nouri et al. (2014) compared the retention of Kerosene, Gasoil or the so-called diesel fuel, gasoline and water as the wetting fluids in soil porous media. They used the soil-liquid retention curve to describe the effect of viscosity of liquid in two-phase systems. Their results showed that petroleum retains stronger than other liquids in soil, while low surface tension of Kerosene, diesel fuel and gasoline provided less retention compared to water.

Variation of soil porous medium permeability caused by petroleum