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Risk assessment for sediment and stream water polluted by heavy metals released by a municipal solid waste composting plant

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ABSTRACT

We determined the levels of various heavy metals in water stream and sediments receiving leachate/runoff from open-air windrows of MSW compost plant of Sanandaj, (Kurdistan, Iran) and assessed the related contamination rate and ecological risk by determining the geo-accumulation index (I_{geo}), contamination factor (CF), ecological risk factor (ER), contamination degree (CD), pollution load index (PLI) and potential ecological risk (RI) of water and sediments. Our results showed that several heavy metals, except Cd, had concentrations higher than the maximum limits for sediments to protect aquatic life, using the Consensus-Based Sediment Quality Guidelines (CBSQG) as reference. Heavy metal concentrations in the stream water were higher than the Canadian Council of Ministers of the Environment (CCME) limits for drinking, irrigation and for protection of an aquatic life, except for Cu and Zn. The evaluation results of the CD and PLI indices showed that the stream water and sediment pollution caused by uncontrolled emission from the open-air windrows composting of MSW, as the elements causing pollution were the same as those enriched in the compost. Values of the ER and RI indices indicated moderate to considerable ecological risk. We concluded that source separation of the MSW and effective control of runoff entering the composting plant are needed to protect the surrounding environment from the negative impact of the composting plant releases.

1. Introduction

With the ever increasing municipal solid waste (MSW) generation due to continuous population growth, the MSW compost generation rate is rising Worldwide and waste management alternatives to landfilling are urgently needed. For example, in the period 2001–2010 in the United States of America and European Union the MSW landfilling decreased by $41 \cdot 10^6$ t whereas MSW composting increased by $28 \cdot 10^6$ t (USEPA, 2006; EEA, 2013), and the same trend is anticipated for other fast growing World's Countries (Themelis and Mussche, 2014; Harir et al., 2015). Use of the compost as fertilizer or soil conditioner or nursery growth medium is a sustainable recycling practice owing to the compost positive effects on soil biological and physico-chemical properties, and on plant growth (Hargreaves et al., 2008; Mylavarapu and Zinati, 2009). Therefore, composting is a feasible management option diverting MSW from landfilling to re-cycle with multiple beneficial effects on the environment by reducing the impact of MSW management, and with positive effects on soil physical and chemical fertility by improving the soil structure and nutrient concentration. However, composting of MSW may result also in environmental risks depending on the site-specific adopted waste collection practice and technologies, and the degree of control during the whole MSW composting process. In fact, the heavy metal concentration of the composting materials can increase making the final use of compost problematic (Achiba et al., 2010). Metal enrichment may require additional treatments to decrease the heavy metal concentrations and impurities prior to land applied of low grade compost (Sharifi and Renella, 2015). A serious problem of MSW composting in open windrows is the exposure of a large surface area of compost to wind and rainfall which may cause leaching and runoff, leading to potential contamination of the surrounding environment with nutrients and heavy metals if not properly controlled (Ule'n, 1997; Krogmann and Woyczechowski, 2000; Larney et al., 2014). While a large amount of information is available on the accumulation of nutrients and heavy metals in MSW derived compost amended soils and on the environmental problems due to MSW landfilling (e.g., Businelli et al., 2009; Achiba et al., 2010; Melnyk et al., 2014; Ghosh et al., 2015), the environmental impact caused by runoff and leaching from the MSW compost is still poorly characterized. Evidence of release of pollutants from compost windrows of cattle, horse and sheep manure through run-off caused by natural or simulated rainfall have been reported (Webber et al., 2009; Ule'n, 1993; Komar et al., 2010; Webber et al., 2011; Larney et al., 2014), but to our knowledge the impacts of runoff from MSW composting sites caused by natural events have been seldom characterized. Poor control of emissions from composting plants can impact receptor bodies such as surrounding soils and water bodies.

The aim of this work was to study the environmental quality in the surroundings of a MSW treatment plant producing compost using an

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open windrow located in Sanandaj (Kurdistan Province, Iran), where the poor control of effluents generated after as rainfall and snowmelt pose the risk of heavy metal contamination to surface water and sediments in the surrounding. This study is important because the contaminated leachate and run-off generated from the composting site finally flows directly into Sanandaj-Kamyaran River that is used to irrigate vegetables and crops.

2. Material and methods

2.1. Site description

Sanandaj, is a city in the Kurdistan province of West Iran (46° 55′ to 47° 5′ E, 35° 12′ to 35° 23′ N). The climate of the area is semi-arid with the mean annual temperature and precipitation 14.5 °C and 439 mm, respectively. The precipitation distribution in this city is irregular with rain peaking in the months of January–April and November–December, with an increased frequency of extreme rainfall (e.g. 142 mm in 25–30 November 2015). According to the Sanandaj Waste Management Organization the current city MSW generation is in the order of 320 t day^{-1}, which is not sorted at source, and consisting of organic fraction (71%), plastics (8%), paper/cardboard (6%), textiles (3%), glass (2%), metallic residues (1%), wood residues (1%) and other substances (8%) (Rezaee et al., 2014). About 200 t of MSW are composted using an open-air windrow system without roof at the Sanandaj MSW Composting Plant (Fig. 1), which are vulnerable to heavy rainfall events, whereas the rest is landfilled. Lack of source separation along with the high initial organic matter content leads to the production of low grade compost, which not used by local farmers and growers because due to excessive salinity, coarse impurities and excessive concentrations of some heavy metals (Sharifi and Renella, 2015). Exposure of open windrows and stockpiled compost to precipitation events cause leaching and run-off especially after heavy rainfall and snowmelt runoff from the elevations of the surrounding watershed. Leaching and run-off are released into a receiving stream, located in the south part of the site. The composting site also has a containment basin which receives the runoff and leachate only from one side and runoff and leachate from composting site (site 1), whereas runoff and leaching from windrows and curing compost piles located below the containment basin (site 2) is uncontrolled and is directly released into the stream (Fig. 1). The contaminated leachate and runoff generated from the composting site joins the Sanadaj-Kamyaran River which is used to irrigate vegetables and crops.

Fig. 1. Map of the site of the compost producing of Sanadaj, Kurdistan Province, Iran, green trigonals showing the sampling points.