Municipal solid waste (MSW): Strategies to improve salt affected soil sustainability: A review

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Abstract

Salt-induced soil degradation is a serious threat to global agriculture which is responsible for diminished productivity of agro-ecosystems. Irrigation with poor quality water and indiscriminate use of chemical fertilizers to increase crop productivity creates salt accumulation in soil profile thereby reducing crop sustainability. High concentration of salts in soil inhibits plant growth due to low osmotic potential of the soil solution, ion toxicity and imbalance reduces nutrient uptake, crop yields. Low productivity of saline soils is not only due to salt toxicity or excess amounts of soluble salts but also lack of available mineral nutrients especially nitrogen, phosphorus, potassium and soil organic matter. Hence, sustainable management of salt-affected soils are paramount importance to meet the demands of food grain production for an ever-rising population in the world. Recently, municipal solid waste has gained importance as an organic amendment for restoring soil fertility and finally contributing to productivity of salt-affected soils. This paper compares extant waste generation, their properties and standards pertinent to municipal solid waste in different countries and explores the unique recent history in some countries that shows high environmental regard and rapid changes and also suggests policy experiencing from high environmental regard and rapid changes from other countries, so that policy makers can propose new or revise current municipal solid waste standards for salt affected soils. Municipal solid waste compost improves soil biological, physical and chemical properties because of high soil organic matter and lower concentration of pollutants. Therefore, the use of municipal solid waste in salt-affected soils could be an alternative to costly chemical amendments as well as reduce the reliance on chemical fertilizers for increasing productivity of salt-affected soil. The municipal solid wastes significantly improve crop yields. However, further long-term experimental investigations are needed to re-validate the application of municipal solid waste compost in improving physical, chemical and biological properties and to step up organic fertilization use in a wide range of both saline and sodic soils. In future, research should be directed to address these issues globally to minimise ecological disturbances and to set environmental standards, and evaluate the feasibility of the policies in different countries and their impact on socio-economic conditions of local people.

Introduction

Rapid population increase, urbanization and industrial growth have led to severe waste management problems in the cities of developing countries like India. India generates 70 million ton of Municipal Solid Waste (MSW) per annum currently and expected to raise approximately 165 million ton by 2031 and by 2050 it could reach around 436 million ton (Planning Commission Report, 2014). The MSW compost is being used by farmers, researchers increasingly in salt affected soils as a soil conditioner as well as organic fertilizer (Wang et al., 2014). MSW in Indian mega-cities is mainly disposed in landfill by means of open dumping; however a small fraction is used for composting. Composting of MSW is considered as an important recycling tool since MSW would otherwise be land filled and lead to environmental and health issues (Cha-um and Kirdmanee, 2011). Apart from the environmental problems, there is a possibility that pollutants from city dumping sites may contaminate the underground water or may be absorbed by plants growing in the nearby agricultural fields and may thus create human and animal health problems (Eriksen et al., 1999).

Soil degradation is a major impediment to sustainable crop production in arid and semi-arid regions of the world. Soil salinity and nutrients deficiency are serious threat to global agriculture (Zhang et al., 2007). Additionally, the increase in the generation of MSW, there is a need to make available more areas for the disposal of wastes in landfill. Therefore, other alternatives of wastes disposal should be studied and evaluates, such as: incineration, gasification and pyrolysis. These thermochemical conversion options would be extremely useful and would corroborate with the reduction of the total volume of wastes (Lakhdar et al., 2011). In addition, the Soil Organic Matter (SOM) fraction of the MSW could be extracted for production of compost. The compost improves soil biological, physical and chemical properties because of the higher SOM (Násner et al., 2017). Approximately 20% of the world's cultivated area and around 50% of the irrigated croplands are affected by soil salinity (Zhu, 2001). Consequently, the affected areas are predicted to be increased with the use of poor quality water and the intensive application of chemical fertilizers (Wong et al., 2005). However, inappropriate irrigation and drainage systems have resulted in rising groundwater levels, which have the potential to trigger salt accumulation in the soil profile and have a negative effect on crop production (Qadir et al., 2009). In addition, limited precipitation, high evaporation and inadequate soil and water management have contributed to an increase in salinity (Leme et al., 2014). The alternate strategies might be (i) vegetative bioremediation- a plant assisted reclamation approach-relies on growing appropriate plant species that can tolerate ambient soil salinity and sodicity levels during reclamation of salt-affected soils. A variety of plant species of agricultural significance have been found to be effective in sustainable reclamation of calcareous and moderately sodic and saline-sodic soils; (ii) second strategy fosters dedicating soils to crop production systems where saline and/or sodic waters predominate and their disposal options are limited (Qadir and Oster, 2004). Production systems based on salt tolerant plant species using drainage waters may be sustainable with the potential of transforming such waters from an environmental burden into an economic asset (Luz et al., 2015). Such a strategy would encourage the disposal of drainage waters within the irrigated regions where they are generated rather than exporting these waters to other regions via discharge into main irrigation canals, local streams, or rivers. Being economically and environmentally sustainable, these strategies could be the key to future agricultural and economic growth and social wealth in regions where salt affected soils exist and where saline-sodic drainage waters are generated (Qadir and Oster, 2004). It is well known that saline soils are deficient in Soil Organic Carbon (SOC), Nitrogen (N), Phosphorus (P) and Potassium (K) (Meena et al., 2016a); antagonism of sodium leads to deficiency of K and Calcium (Ca) (Marschner, 2012). Excess salt concentration (Na^+) adversely not affects only the soil physico-chemical properties, especially the structural stability and bulk density, which strongly compromise with crop productivity but enhances the dispersion of clay, thus decreasing soil permeability also. As per Centre Pollution Control Board, India Ca in the range of 40–100 ppm, and Magnesium (Mg) in the range of 30 to 50 ppm are considered desirable for irrigation water.

Acceptable levels of Sodium (Na) and Chloride (Cl) for ornamentals are <50 ppm and 140 ppm, respectively, however higher levels may be tolerated depending on crop sensitivity. Permissible limit of Sodium Adsorption Ratio (SAR) and boron (in ppm) is 26 and 2 for irrigation, respectively. Sodicity causes structural problems in soils created by physical processes such as slaking, swelling as well as conditions that may cause surface crusting and hard setting (Quirk, 2001). Such problems affect water and air movement, plant-available water holding capacity, root penetration, runoff, erosion and tillage and sowing operations; subsequently, imbalances in plant-available nutrients in both saline and sodic soils affect plant growth (Meena et al., 2016b).

Establishment of sustainable techniques for managing salt-affected soils and increasing crop productivity are needs of the hour. The restoration of microbial activity is a basic step for reclamation of saline soil (Meena et al., 2016a) because microbes have potential to reinstate the fertility of degraded land through various processes. These microorganisms increase the nutrient bioavailability through nitrogen-fixation and mobilizations of key nutrients (phosphorus, potassium and iron) to the crop plants while remediate soil structure by improving its aggregation and stability (Qadir and Schubert, 2002). Though, success rate of such processes under field conditions depends on their antagonistic or synergistic interaction with indigenous microbes or their inoculation with organic fertilizers. Maintenance of adequate soil physical and chemical properties of saline soil may be achieved by using good quality water, rational use of chemical fertilizers, integrated use of organic amendments and appropriate cultural practices (Grattan and Oster 2003). Of late, many technologies has been developed for reclamation of salt-affected soil, as physical amelioration (deep ploughing, sub-soiling, sanding, and profile inversion), chemical amelioration (amending of soil with various reagents: gypsum, calcium chloride, and limestone) and electro-reclamation (treatment with electric current) (Raychev et al., 2001). Alternatively, salt tolerant plant species can be only cost effective means of getting higher crop yield (Abdelly et al., 2006). Several organic amendments, such as MSW, manures, and composts have been investigated for their positive role in soil remediation (Meena et al., 2016b), and they have been reported to improve soil sustainability. Application of organic amendments improves physical, chemical and biological properties of salt-affected soils, and SOM, eventually. Meena et al. (2016a) noted that application of organic amendments increased nutrient concentrations especially NPK, organic carbon, microbial biomass and enzymatic activities in salt-affected soils. The MSW Compost (MSWC) has two beneficial effects on reclamation of saline soil: improvement of soil structure and permeability thus enhancing salt leaching, reducing surface evaporation and inhibition of salt accumulation in surface soils, and release of CO_2 during respiration and decomposition of compost (Raychev et al., 2001). However, potential ecological and health risks may arise due to nutrient transport to ecologically sensitive receptors and accumulation of trace elements in the soil profile and their entry in food chain (Smith, 2009). These issues should be carefully addressed in order to mitigate the environmental impacts and optimize compost use in agriculture. For these reasons, many states/countries have developed specific guidelines regulating its safe use, although they are still under discussion (Barral and Paradelo, 2011).

The study of environmental standards from different countries applicable to MSW is not widely published, much less those for MSWC. Previous studies have addressed the effect of MSWC/MSW on soil properties, crop yield and environmental issues separately and the studies are also region specific. There has been a lack of suggestions for management of ill effects of

MSW. Insufficiency of holistic knowledge on MSWC quality and maturity also has generated confusions among readers; also information regarding these issues on a global basis is scanty. This paper compares extant waste generation, their properties and standards pertinent to MSW in different countries and explores the unique recent history in some countries that shows high environmental regard and rapid changes and also suggests policy experiencing from high environmental regard and rapid changes from other countries, so that policy makers can propose new or revise current MSW standards for salt affected soils.

The purpose of this review paper is to investigate the effects of MSWC as an ameliorant and soil conditioner to alleviate the negative effect of salt-affected soils. In future, research should be directed to address these issues globally to minimise ecological disturbances and to set environmental standards, and evaluate the feasibility of the policies in different countries and their impact on socio-economic conditions of local people.