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Urban Solid Waste Management for Enhancement of Agriculture Productivity in India

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ABSTRACT

In India currently rapid industrialization and population explosion produce huge quantity of solid waste daily. About 40 - 50% of that waste is collected by the municipality while rest of it remains unutilized. Generally lack of sanitary landfills, solid wastes accumulated in the open places, causing trouble and unhealthy environment. Subsequently it leads to contamination to soils, air, groundwater, surface water and finally creating human health hazards. The suitable management pratices of solid waste, the technology to prevent and minimize waste and maximization of recycling and utilization ecofriendly alternative materials is the need of the hour. Instead of landfilling or incineration of Municipal Solid Waste (MSW), with the advent of modern technology, it can be utilized in agriculture as a fertilizer for plants and amendment to improve the soil health. Conversion of MSW through composting endorsed its use in agriculture which resolve difficulty of discarding and enhance the agricultural productivity. MSW compost (MSWC) application in agricultural soils improved soil ecology and fertility through the build up of soil organic carbon. Moreover, Government policy and guidelines are urgently required in our country to facilitate the municipal corporations to improve the waste management services.

Keywords Solid waste, Agriculture, Compost, MSW, Soil.

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INTRODUCTION

The term municipal solid waste (MSW) describes the stream of solid waste generated by households food waste, agricultural waste, human and animal wastes. The production of MSW is an inevitable consequence of today's consumer society. The rate, quantity and quality of the municipal solid waste production is highly hasten by rapid urbanization, overburden population, rise in economy and higher standard of living in developing countries (Minghua *et al.* 2009, Erasu *et al.* 2018). Municipalities, usually to responsibility for the management of waste within the cities, have the challenge to afford associate degree economical and effective system for the inhabitants (Smith *et al.* 2019). There are no reliable estimates of municipal solid waste production in India. The Report of the Task Force on Waste to Energy of the Planning Commission in 2014 estimates MSW generation at 62 million tonnes in 2013-14. Assuming urban population of 440 million in 2017 and per capita daily waste generation of 450 g, the MSW produced for 2017 comes to 72 million tonnes (Kasturirangan *et al.* 2014). Composting and anaerobic digestion are only the known conventional technologies for the treatment and valorization of the organic fraction of MSW. Finding safe, sustainable and cost-effective alternatives to the disposal of MSW in landfills represents a major challenge to the waste management industry. Recycling and composting are seen as attractive waste management options, providing that there are few negative effects on the environment. Like other manures, urban compost also releases different nutrients during decomposition in soil. The application of garbage compost in soil significantly improvement in pH, organic matter, major, secondary, and micronutrients (Khan *et al*. 1981).The biological activities in soil are also aggravated by acting on food substrate to the native soil microflora, as reflected by CO_2 evolution, ammonification and nitrification. Several workers carried out research work on the use of garbage compost for maximizing agricultural production under limited availability of fertilizers (Pelletin *et al*. 1986, Prince 2003, Rodríguez-Meizoso *et al*. 2010). The role of organic products is not only as bio-fertilizers but also its possible bio-stimulant action (Rodríguez-Meizoso *et al.* 2010). Urban waste application in agricultural soil helps to check soil erosion loss, develop good soil structure and augment the nutrient content in soils. Recommendation of organic manures in soils under intensive cropping system is essential to improve soil structure, enhance the water holding capacity and nutrient availability to plants. This primordial practice has positive influence on soil fertility, but the chemical composition, the capacity to supply nutrients to crops and effect on soil vary depending on origin, age and content management humidity (Prince 2003). Urban wastes can be used as an alternative source of fertilizers but its management is quite challenging and also the production as per requirements of the farmers is to be urgently addressed. Application of compost in soil helps to replenish the diminishing of organic matter content in cultivated soils and to recycle organic wastes. It also improves the soil aggregate stability which provide better crop growth (Annabi *et al*. 2007). Soil hydrodynamic properties gets improved through increase in soil porosity due to application of urban waste and it is a direct consequence of enhanced soil aggregation (Pagliai *et al*. 2004). But depending on the incorporated organic matter quality the degree of improvement of soil health occurs. In 2010-11, Coromandel International Ltd (CIL) marketed 50,000 tonnes of compost generated from municipal solid wastes (MSW). Besides CIL, Nagarjuna Fertilizers and Chemicals, Zuari Industries, FACT, Kribhco and National Fertilizers Ltd are also marketing MSW-based compost at mini-scale level. India's total MSW-based compost production is now at 2.5 lt. The potential is much larger, given the roughly 500 lt of MSW generated annually by the cities and towns here. That works out to 140,000 tonnes a day (tpd), with Delhi and Mumbai alone contributing 9,000 tpd each, Chennai and Kolkata 5,000-6,000 tpd and Bangalore and Hyderabad 4,000-5,000 tpd. IL and FS Environmental Infrastructure and Services Ltd (IEISL) operates composting units at Delhi, Jalandhar, Mysore, Kozhikode, Erode, Pollachi, Mettupalayam, Udumalpet and Coonoor, process 1,480 tpd of MSW (Harish 2018). Another 900 tpd added through new facilities at Jaipur and Tiruchi and expanding its 200-tpd plant at Delhi to 500 tpd (A2Z Infrastructure has the country's single biggest facility of 1,800 tpd at Kanpur, followed by Hanjer Biotech's 800-tpd unit at Nagpur). Generally organic carbon content (OC) in Indian soils is low, due to its arid and semiarid climate and intensive cropping system. By application compost enhanced the organic carbon content in soil and also the nutrient use efficiency of the chemical fertilizers applied by them.

Higher organic carbon content in soils improves water-holding capacity, soil tilth and its porosity. IEISL reported that groundnut seedlings will survive better in compost-treated soils as compared to control soil. Application of compost also enhanced the number of tillerings and favored better root growth. Similarly farmers surroundings Agra in Uttar Pradesh have raised per-acre yields of wheat from 16 to 21 quintals by the application of urban waste compost in integration with regular fertilizers. A total of 12,710 tons of household wastes was produced from households in Ghana. 8389 tons of the waste are biodegradables and used for bioconversion processes and 2754 tons for recycling. National sorting and separation efficiency was 84% for biodegradables and 76% for other waste. The one way separation system was effective (Kodwo *et al*. 2015). The National and State Governments have given an momentum to improve the solid waste management in urban areas under various programs and schemes. The Jawaharlal Nehru National Urban Renewal Mission (JnNURM) funded 49 SWM projects in various cities between 2006 and 2009. Several cities in India have taken positive steps towards implementing sustainable waste management practices by involving the community in segregation, by enforcing better PPP contracts and by investing in modern technology for transportation, processing and disposal. The role of waste pickers/ informal sector in SWM is also increasingly being recognized. These interventions have great potential for wider replication in other cities in the country. Besides, a decentralized system can help to sort out the intractable challenges and problems of waste management in low-income developing country cities in a socially favorable, economically viable and environmentally friendly manner (Zohoori and Ghani 2017).

Types and sources of urban waste

Promotion of organic manure from city garbage is gaining momentum as a good business, even chemical fertilizer companies eagerly including it in their product base Fig 1. The composition of MSW represented in Fig 2. When applied to land, these residues have the potential to significantly increase soil organic matter (SOM) contents, an aspect that is in critical decline in many regions of the world, particularly in more arid environments (Bellamy *et al*. 2005). Maintaining and increasing soil organic matter stocks, a key soil quality indicator, is now seen politically as a key priority for preserving ecosystem function. Numerous trials have shown that addition of MSW compost to soil can at least transiently increase SOM contents as well promoting soil biological activity. Additional benefits of compost addition also include reduced erosion losses, a decrease in bulk density and improved structural stability. Regardless of the risks of heavy metal pollution, if applied responsibly MSW compost can improve nutrient availability and plant uptake in agricultural soils. MSW compost can provide similar amounts of P to mineral fertilizers in some soils. For typical application rates of 10–100 t/ha, the uncertainty over nutrient availability during a cropping season also makes it difficult to accurately predict crop demands and therefore optimal compost application rates in comparison to conventional inorganic fertilizers. In a study investigating the growth and nutrient content of maize under different additions of MSW compost, although yield did not increase over their control treatment, maize grains from compost-treated plots were enriched in C, N and P as a result of the increased nutrient status of the soil. MSW compost produced comparable yields to chemical N addition and improved forage yields over solid manure addition. Quality of the crop (fibers and energy), and residual nitrates were similar to those from the inorganic treatment. In addition to erosion reduction and increased soil stability, the addition of composts to agricultural soils has been found in increase the water holding capacity of soils. The application of two paper-based composts increased the amount of water held both at field capacity (0.05 MPa) and permanent wilting point (1.5 MPa) in a loamy sand soil (Foley and Cooperband 2002). Since the increase in water held at field capacity increased to a greater extent than at wilting point, it can be inferred that plant available water increases following compost addition to soil. Growth of maize on a loamy sand soil using MSW composts produced mixed results, increasing the soil water holding capacity without greatly increasing the estimated plant available water within the soil. They concluded that increases in water stress in the corn may also be due to increased salt loading in the soil due to the relatively high electrical conductivity of the compost. However, one year after the application of MSW compost, soil water content increased, along with corn yield and an associated reduction in plant water stress. There is unfortunately a shortage of data on the effects of different compost amendment regimes on plant available water within soils and further research is required in this area. With future changes to climate and rainfall patterns, this area of research will become increasingly important treatment. In addition to erosion reduction and increased soil stability, the addition of composts to agricultural soils has been found in increase the water holding capacity of soils. The application of two paper-based composts increased the amount of water held both at field capacity (0.05 MPa) and permanent wilting point (1.5 MPa) in a loamy sand soil. Since the increase in water held at field capacity increased to a greater extent than at wilting point, it can be inferred that plant available water increases following compost addition to soil. They concluded that increases in water stress in the corn may also be due to increased salt loading in the soil due to the relatively high electrical conductivity of the compost. However, one year after the application of MSW compost, soil water content increased, along with corn yield, and an associated reduction in plant water stress. There is unfortunately a shortage of data on the effects of different compost amendment regimes on plant available water within soils and further research is required in this area. With future changes to climate and rainfall patterns, this area of research will become increasingly important.

Composting of urban waste

Composting is defined as the biological decomposition of organic matter under controlled aerobic conditions to form a stable humus- like end product. The process is facilitated by a diverse population of microbes, whose population dynamics vary greatly both temporally and spatially and generally involves the development of thermophilic temperatures as a result of biologically produced heat. Inoculation of MSW with specific organisms can also enhance the speed of composting. The organic matter contained in MSW feedstocks can range from garden and food waste to mixed household wastes, the biodegradable proportion varying from 50% to 90% depending upon country. Heavy metals high levels of heavy metals (e.g., Cd, Cr, Cu, Pb, Ni and Zn) in composts represent an obvious concern if they are to be applied to food crops . Heavy metals do not degrade throughout the composting process and frequently become more concentrated due to the microbial degradation and loss of carbon and water from the compost. The levels at which these elements are found can vary from negligible background levels in 'clean' composts such as source-separated food waste, to potentially toxic levels in some mixed waste based composts. The total heavy metal contents of several MSW composts in comparison to current compost quality standards. It is clear that MSW composts exceed the tolerable levels for most metals in comparison to UK standards. There are many sources of heavy metals within household waste, many of which can pass through mechanical screens designed to remove non-biodegradable components (e.g., Ni, Zn and Cd containing batteries). The potential for contamination of MSW is exacerbated by the poor availability of recycling facilities for hazardous wastes and poor public attitudes to waste management. In addition to the obvious 'point sources' of heavy metals (e.g., batteries), other materials such as paints, electronics, ceramics, plastics and inks/ dyes can all contribute to the heavy metal burden of MSW. Overall, however, information on the sources, quantities and behaviour of heavy metals and other hazardous substances in MSW is lacking. Total metal contents in compost are of concern when repeated applications to land occur. Field tri involving MSW compost application to soil have all reported an increase in soil and plant metal concentrations (e.g., Ni, Pb, Zn and Cu). Generally, whilst increasing the overall heavy metal burden of the soil may be undesirable, application of composts poses little risk in terms of phytotoxicity or metal contents of crop tissue. This is probably due to the relatively small proportion of the heavy metal contained in the compost that are environmentally available. Metal bioavailability also reduces with length of composting due to several processes which bind metals including complexation and sorption with organic matter, microbial immobilization and oxidation. Of these, humification of organic matter which creates sorption sites, is thought to be the primary mechanism affecting metal availability during the composting process. Conversely, the amount of water-soluble organic carbon, which complexes metals rendering them non-bioavailable, tends to decline during composting. It is therefore clear that the compost needs to be mature to ensure that heavy metal availability is reduced, particularly as partially oxidized composts are known to reduce crop yields. In conclusion, whilst some concerns have been raised about potential disruption to localized ecosystem functioning, there is also a great deal of evidence to suggest that dilution factors of soil and water reduce this risk to a minimum. The risk of metal contamination from MSW-derived composts is of similar magnitude to that posed by biosolids application to land which is now a widely accepted practice.

Organic pollutants compost feedstocks are known to contain significant levels of various organic contaminants, including polynuclear aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/Fs) and polychlorinated biphenyls (PCBs), however, there is still scant information on their concentrations and behavior in MSW-derived composts. These organic contaminants can have a pronounced mutagenic and carcinogenic potential and can be extremely persistent in the environment. In addition, some compounds such as PAHs are barely affected by abiotic degradation processes such as hydrolysis and photodegradation. Kitchen wastes and organic household wastes are expected to be contaminated with POPs due to co-disposal with non-biodegradable wastes (e.g., plastics and electrical equipment). In a range of green waste composts, the median PAH concentration was 1.7 mg kg1 , as opposed to 1.9 mg kg1 in composted MSW suggesting little difference. Similar results were also obtained for PCBs and PCDD/Fs . As yet no international standards exist for organic pollutants in compost. It also remains difficult to compare studies due to differences in sample preparation and instrumentation used in analysis. Further, our experience, alongside others, is that the multitude and complex nature of organic compounds in compost makes the potential for experimental bias and error extremely large (e.g., incomplete extraction, compound misidentification and inaccurate quantification). Despite these reservations, generally low levels of PAHs in 24 industrial composts, with levels below those permitted for biosolids destined for agricultural land. Current evidence suggests that composting is crucial for reducing the pollutant load of MSW and MBT residues. The initial thermophilic phase is suitable for removing volatile pollutants whilst other more labile compounds are broken down by bacteria and actinomycetes (e.g., low MW PAHs). The final maturation phase, where mesophilic fungi become prevalent, is the most effective for the removal of more recalcitrant POPs (e.g., high MW PAHs). Many POPs also become bound into hydrophobic organic residues during the composting phase making them less bioavailable at least in the short term. In conclusion, composting provides a critical step in the treatment of MSW and MBT residues for organic pollutant removal, however, our understanding is lacking in several key areas. Firstly, the amount and concentration of many POPs and their temporal and spatial variability has yet to be established both within the feedstock material and the resulting compost. Secondly, the optimal conditions for organic pollutant removal during composting have yet to be established preventing effective management and the formulation of industrial guidelines. Thirdly, the relative importance of the mechanisms by which organic pollutants are made less available (volatile phase, solid phase immobilization and microbial breakdown) needs investigation to assess whether further technological advancements can be made to enhance their removal. Agronomic and horticultural use represents a large potential market for MSW compost, therefore, from a disposal perspective soils potentially represent an almost infinite sink for organic residues. The nutritive value of MSW composts (Fig 3) and their potential to enhance soil quality makes them ideal for agriculture, provided that correct precautions are taken to mitigate against environmental damage and to gain public acceptance. The addition of compost to agricultural land may unnecessarily increase the heavy metal content of the soil. At normal application rates, however, there is little risk.

Urban solid waste management

Municipal solid waste management (MSWM) is one of the most ignored basic services provided by the Government of India. Generation and characteristics of MSW may vary at the level of country, state, city as well as within different areas of the same city (Table 1). Soil application of urban waste could be a good alternative as it is rich in organic carbon and has high nutritive value. Composting/vermin-composting of MSW could be good selection for MSW in developing countries because its high nutrient content and is pathogen free. A suitable planning is required for MSWM. Before designing a SWM plan, the population, climatic condition, socio-economic condition, solid waste nature, financial support, environmental pollution, health impact should be investigated. Besides this systematic planning and implementation, designing ISWM system, source segregation, 4Rs (Reduce, reuse, recycling and recovery) strategy for waste minimization, GIS application for MSW management, decentralized composting at micro level, compliance of MSW rules, user-charge system based on income, prohibition of open burning, separate treatment for biomedical waste, awareness programs, involvement of formal / informal stakeholders and promotion of R and D should be considered for proper management of MSW.

Road map, planning and future policy

Urban waste composting would be recognized when there is high demand of city compost by the farmers. Huge government subsidy on fertilizers (Urea, MOP, DAP) hides the actual price or expenditure for fertilizer production and diminish the demand for urban waste compost. The Government's target to reduce the quantity of urea application in agricultural field to its half by 2022 is a right approach but it has to be supported with subsidy reduction on Urea. The co-marketing of urban waste compost is not the right approach. Fertilizer companies should accept urban compost at reasonable prices and conditional fertilizer subsidy on procurement of compost would be the way forward. Assured good quality urban compost, without heavy metals and other toxic elements, for sale to the farmers, will also increase the demand for it. Farmers' perception about the lower productivity of compost as compared to fertilizers should be defyed by propagation of knowledge and field demonstration of the benefits of using compost, (KVK, Extension Workers). Revised Municipal Solid Waste Management Rules were formulated in the year of 2016 to facilitate solid waste management in India. Besides that, JNNURM, AMRUT, Smart Cities and Swachh Bharat Mission. national missions were also started by the Government of India to address the multiple challenges of municipal solid waste management. But no such progress was recorded to mitigate the problem. Firm and focused steps should be taken to convert the Rules and the Missions into reality (Some points may be considered as follows:

Development of waste treatment systems

A successful development from experimental to full-scale waste treatment systems, offers several advantages by using the larvae of the black soldier fly. Since such systems can be developed, implemented and operated at low cost, they are more adapted to the developing countries.

Utilization of smart solid waste compactors

Breaking the boundaries conventional waste compactors have, Waste Compactor is made to provide solutions to many present garbage collection issues. With superior performance and wide serviceability, solid waste compactor is suitable for use in both urban and rural areas.

Motivations for urban farming

The most of the urban farmers have a positive perception regarding the utilization of urban waste. The main reasons for using urban waste is its effectiveness as a fertilizer, as a soil conditioner and for the improvement of soil texture, crop yield and health of plants. Application of urban waste has a positive impact in the long run, especially as a soil conditioner, including improvement in soil texture, water retention capacity and subsequently enhances fertility and crop yield.

Extension and proper communication

One of the major prroblems to sustainable food production in and around developing cities is the lack of communication on urban agriculture among its actual and future practitioners, be they researchers, city farmers, urban planners, consumer organizations, city administrators, national and international support organizations and other stakeholders in urban agriculture.

Awareness amongst the potential users

Campaigning proper composting and popularising its use among urban farmers is the major step. Lack of a vigorous marketing strategy and the ready availability of chemical fertilizers, demand for compost continues to be low. Neither is there enough awareness among potential users about its benefits in terms of crop yield and environmental benefit. There is thus a need for reversal of this trend through communication, to facilitate sustainable development in urban agriculture. The medium of communication must not only be for experts, but should address all types of stakeholders including the city farmers themselves.

CONCLUSION

Involvement and role of a number of government stakeholders like Ministry of Environment and Forest (MoEF), Ministry of Urban Development (MoUD), Ministry of agriculture, Ministry of New and Renewable Energy and Ministry of Non-Conventional Energy Sources (MNES) in MSWM is urgently required to manage the urban waste. Besides, the involvement of formal and informal sector could help MSWM. So there is a need of a holistic approach like integrated solid waste management (ISWM) and comprehensive effort from all dominion of society to sustain the agricultural productivity. Enriched in biodegradable organic matter, suitable moisture content and proper C/N ratio in urban solid waste made it a suitable staff for composting. However, the composting process and compost quality could further be improved by adding inoculating agent like cow manure, poultry manure, yard waste. in the urban solid waste. Since sandy soil is erodible, low water holding capacity with little organic matter and nutrient content, the application of compost would be an investment in the long term for the health of soils and plants. A module of this type for the recovery of valuable and economical organic fertilizer- the compost, can be adapted country wide to recycle the urban solid waste as waste management option. The municipal solid wastes significantly improve crop yields. Moreover, further long-term experimental investigations are required to re-validate the application of municipal solid waste compost for the betterment of physical, chemical and biological properties of soil and to boost crop yield.

Recommendations

The existing urban waste compost practices in India should be improved and well structured based on currently formulated different national schemes. Some recommendations pointed out below for further refinement:

Awareness amongst the common people is urgently required regarding the importance of source segregation at production point as biodegradables, inert and recyclable material for appropriate urban waste management.

In India, more number of composting plants should be installed in different areas of the cities for smooth functioning of the plants.

Government should help and encourage academic and technical institutions to create infrastructure which facilitate characterization of waste in their vicinity. It will pave the way for the development location-specific appropriate solutions for urban waste management.

Indian government should take initiative to develop a policy, fiscal intensive and development of quality standard for reuse urban solid waste for sustainable agriculture.

Environmental research program should be initiated to sort out the problem like plastic and leachate contamination in ground water, heavy metal pollution in soil which in future provides us the appropriate technological solution to remove this barrier for safe use urban waste compost to sustain Indian agriculture.

REFERENCES

Annabi M, Houot S, Francou C, Poitrenaud M, Bissonnais Y Le (2007) Soil aggregate stability improvement with urban composts of different maturities. *Soil Sci Soc Am J* 71:413–423.

Bellamy Pat H, Loveland Peter J, Bradley Ian R, Murray Lark, Guy R, Kirk JD (2005) Carbon losses from all soils across England Wales 1978–2003. *Nature* 437: 245–248.

Erasu Duguma, Tesfaye Faye, Amaha Kiros, Abel Balew (2018) Municipal solid waste generation disposal in Robe town, Ethiopia, Journal of the Air & Waste Management Association, DOI: 10.1080/10962247.2018.1467351.

Foley BJ, Cooperband LR (2002) Paper Mill Residuals Compost Effects on Soil Carbon Physical Properties. *J Environ Qual* 31 (6): 58-66 2086.doi:10.2134/jeq2002.2086.

Harish Damodaran (2018) Urban waste, no longer trash for fertilizers firms. *Agric Business August* 22: 15-19.

Kasturirangan K *el al*. "Report of the Task Force on Waste to Energy" Planning Commission, Government of India (2014) Accessible at: planning commission.nic.in.

Khan G, Gupta SK, Banerjee SK (1981) Studies on solubilization of phosphorus in the presence of different city wastes. *J Ind Soc Sci* 29: 120-126.

Kodwo Miezah, Kwasi Obiri-Danso, Zsófia Kádár, Bernard Fei-Baffoe, Mensah Moses Y (2015) Municipal solid waste characterization quantification as a measure towards effective waste management in Ghana. *Waste Manag* 46: 15–27.

Minghua ZF, Xiumin A, Rovetta H, Qichang F, Vicentini L, Bingkai A, Giusti L, Yi J (2009) Municipal solid waste management in Pudong New Area, China. *Waste Manag* 29: 1227–1233.

Pagliai M, Vignozzi N, Pellegrini S (2004) Soil structure the effect of management practices. *Soil Till Res* 79: 131–143.

Pelletin J, Letard M, Barbo P, Quiliec SL, Amiard JC, Berthet B, Matayer C (1986) "The Use of Town Refuse Composts Sewage Sludge Composts in Vegetable Production", Cashiers duCTIFL, France.

Prince Edward Island, Canada (PEIC) (2003) "Important

Soil Properties" Dept of Agriculture Forestry, http://www.gov.pe.ca/af/agweb/index, php3?number=71773.

Rodríguez-Meizoso I, Jaime L, Santoyo S, Señoráns FJ, Cifuentes A, Ibáñez E (2010) Subcritical water extraction characterization of bioactive compounds from *Haemato coccus pluvialis* microalga. *J Pharm Biomed Anal* 51:456–463.

Smith J, Nayak DR, Albanito F, Balana BB, Black HIJ, Boke S, Phimister EC (2019) Treatment of organic resources before soil incorporation in semi-arid regions improves resilience to El Niño and increases crop production economic returns. *Environ Res Lett* 14(8): 1-12. [085004]. https://doi.org/10.1088/1748-9326/ab2b1b.

Zohoori M, Ghani A (2017) Municipal solid waste management challenges problems for cities in low-income developing countries. *Int J Sci Engg Appl* 6: 2-8.