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Estimation of municipal solid waste generation and landfill area in Asian developing countries

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Abstract: *In developing Asian countries, the municipal cooperations are unable to handle the increasing amount of municipal solid waste, which into the uncollected waste being spread on roads and in other public areas leading to tremendous pollution and destruction of land and negative impact on human health. Generation of municipal solid waste increases with the rapid urbanization and accelerated economic development with in the rapidly growing advanced technological societies. The nature of municipal solid waste is a term usually applied to a heterogeneous collection group of waste produced in urban areas, the nature of which varies from region to region. The common problem faced by all developing Asian countries, is the disposal of municipal solid waste and availability of land fill site area. Present study explains the correlation analysis of among different factors of municipal solid waste and the objective is to assess the future municipal solid waste stream in Asian developing countries. The other goal of this study was to calculate the future land area that would be required for landfill site disposal in Asian developing countries.*

Key words: *Municipal solid waste, Urbanization, Waste generation, Landfill area, Asian developing countries*
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Introduction

Municipal solid waste generation is an issue of worldwide concern. The generators of municipal solid waste are broadly classified as residential, industrial, commercial, institutional, construction, demolition, municipal and agricultural types (Sehker and Beukering, 1998). Municipal solid waste is also generated by human and animal activities that are discarded as useless or unwanted waste. Economic development, urbanization and improving living standard in cities of developing countries have lead to increase in the quantity and complex composition of municipal solid waste. Management of municipal solid waste resulting from rapid urbanization has become a serious concern for government departments, pollution control agencies, regulatory bodies and public in most of the developing countries (Glawe *et al.,* 2005; Erdogan *et al.*, 2008).

Several other factors like education standard and infrastructure of the country have significant effect on municipal solid waste generation. The estimation and prediction of municipal solid waste generation play an important role in municipal solid waste management. The quantity of municipal solid waste in developing countries has been consistently rising over the years (Kansal, 2002). The municipal solid waste composition varies from place to place and also bears a rather consistent correlation with the average standard of living (Visvanathan and Trankler, 2003). The waste generated in the developing countries is similar in composition, the variation between regions being dictated by the climatic, cultural and industrial, infrastructural and legal factors.

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Inefficient management and disposal of municipal solid waste is an obvious cause for degradation of environment in the developing countries. Ecological impacts such as land degradation, water and air pollution are related with improper management of municipal solid waste (Khajuria *et al.,* 2008). In Asian developing countries, most of the municipal solid waste is dumped on land in more or less uncontrolled manner. Lack of sufficient awareness at the grassroots level of the waste generators add to the problem of littering. As a result there is a serious threat to public health due to environmental pollution. This paper describes analyses the correlation analysis of among various factors of municipal solid waste generation and also estimates the future amount of municipal solid waste generation. Finally, the future land area required for landfill site disposal in Asian developing countries is also calculated.

Materials and Methods

Determination of municipal solid waste generation factors:

Urbanization: Developing countries are producing municipal solid waste at an alarming rate. From the last two decades, the amount of municipal solid waste has been increasing rapidly. This is particularly due to the rapid growth of urban areas and migration of population from rural to urban areas (Fig. 1).

Gross domestic product per capita (GDP per capita): In developing countries, improvements in economic conditions have changed the living standard and increase the rate of consumption of materials. Subsequently, it causes the generation of large amount of municipal solid waste (Fig. 2). GDP per capita is the gross domestic

product calculated according to GDP Wikipedia, 2001 and World Bank, 2007.

Illiteracy / level of public awareness: Illiteracy and lack of public awareness also contribute towards the generation of municipal solid waste. Unsegreggated or mixed municipal solid waste generation and illegal disposal methods on the increase due to the low level of public awareness (Hockett *et al.,* 1995).

Sanitary services: In developing countries, rate of sanitary services such as sewerage, wastewater treatment, septic tanks and latrines are very low, especially in rural areas. Urban community has also made slow progress in providing wastewater treatment. The lack of proper infrastructure for sanitation services plays an important role in the increase of municipal solid waste.

The easiest method of correlation is a linear model, which assumes a linear relationship between the amount of municipal solid waste generation and their contributing factors.

$$WG = a + \beta x_1 + \alpha x_2 + \gamma x_3 \quad (1)$$

where WG is the amount of municipal solid waste generation and x_1 is population, x_2 is GDP per capita and x_3 is Illiteracy rate. a, sym α, β and γ are the coefficient of correlation variables.

Forecasting of municipal solid waste generation: The mathematical calculation is a ultra process beginning with the estimation of future population based on the present trend and then calculate the future amount of municipal solid waste generation (Weber, 2004 of studied countries.

$$\text{Future population} = \text{Initial population} (1 + \% \text{ growth rate}/100)^{\text{years}} \quad (2)$$

Future amount of municipal solid waste generation= (Predicted population) x (Waste generation rate) x (Number of day) ÷ (1000 kg per metric ton) (3)

Forecasting of landfill area:

Formulation to estimation of the future landfill area: The future landfill area was calculated according to Gerard, 1998.

$$\text{Volume of land, filling space annually required } (m^3\ yr^{-1}) = \frac{(\text{Waste million tonnes } yr^{-1}) \times (10^3)}{\text{density of waste in kg } m^{-3}} \quad (4)$$

$$\text{Required land area } (m^3) = \frac{(\text{Waste } yr^{-1} \times 10^3)}{\text{Standard height}} \quad (5)$$

This value will need to increase by about 1.5 percent to allow for daily cover, roads, receiving areas, fencing, *etc.* therefore,

$$\text{Required area (ha)} = (\text{hectare}) \times (\text{years}) \times (\text{height}) \quad (6)$$

Results and Discussion

Estimation of urban population and generation of municipal soild waste: In the year 2000, about 30% of the rural population in the Asian region lived in cities. In Asian developing countries, urbanization trend have is expected to gained momentum from 2007 to 2030s. In India, the urbanization rate was expected to increase by an average of 12.28 to 32.43% from 2007 to 2030. Other studied countries like Nepal, Pakistan, Bangladesh and Sri Lanka have been experiencing a gradual rise in their urban population, but this growth has been intensive in several major cities.

Rapid urbanization in Asia has been synchronous with dramatic rate of economic growth as well as severe environmental problem. This increase puts more pressure on the partially existing municipal solid waste management infrastructure (Brinkhoff, 2005). As the pace of urbanization accelerated, environmental problems may get be worse due to inadequate growth of urban environmental infrastructure. Municipal solid waste generation has been increasing proportionately with the growth of urban population (Table 2).

The development of technological and advanced society with economic growth in Asian developing countries may cause the major effect to increase the quantity of municipal solid waste generation. The quantity of municipal solid waste and the proportion of the constituents also vary from season to season and place to place

Table - 1: Show the calculation of correlation coefficient of using different variables related to municipal solid waste generation of 2001-2007

	POP	UP	GDP	ILL
		India		
WG	0.988	0.986	0.951	0.982
POP		0.564	0.383	0.478
UP			0.904	0.985
GDP				0.940
		Nepal		
WG	0.889	0.786	0.461	0.680
POP		0.977	0.310	0.189
UP			0.178	0.981
GDP				0.393
		Pakistan		
WG	0.985	0.979	0.955	0.978
POP		0.980	0.958	0.982
UP			0.986	0.956
GDP				0.930
		Bangladesh		
WG	0.992	0.820	0.883	0.976
POP		0.980	0.864	0.965
UP			0.911	0.978
GDP				0.828
		Sri Lanka		
WG	0.981	0.965	0.916	0.856
POP		0.976	0.990	0.888
UP			0.974	0.818
GDP				0.887

Where, WG= Waste generation, POP=Population, UP=Urban population, GDP=Gross domestic product and ILL=Illiteracy. Source: (World fact sheet, 2001)

Table - 2: Future prediction of urban population, GDP per capita and municipal solid waste generation per capita of studies countries

	Urban population (% in total)			GDP per capita (%)			Municipal solid waste generation per capita (kg day^{-1})		
	2007	2010	2030	2007	2010	2030	2007	2010	2030
India	12.28	17.35	32.43	5.3	6.0	7.0	0.75	0.79	0.97
Nepal	15.25	21.87	38.65	2.0	3.0	4.2	0.32	0.35	0.44
Pakistan	17.93	25.10	45.00	4.2	4.8	5.2	0.39	0.44	0.59
Bangladesh	18.03	25.37	44.45	4.7	4.8	5.0	0.67	0.73	0.98
Sri Lanka	12.27	17.35	32.43	4.7	4.9	5.3	0.56	0.59	0.73

Source: (World fact sheet, 2001) and (World Bank, 2003)

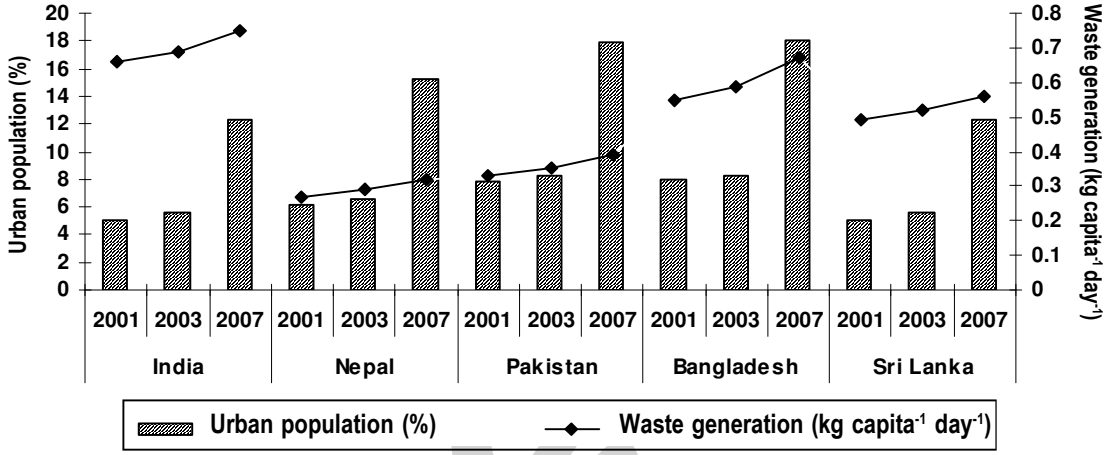

Fig. 1: Relationship between urban population and waste generation of studied countries in 2001-2007. Source: (World fact sheet, 2001)

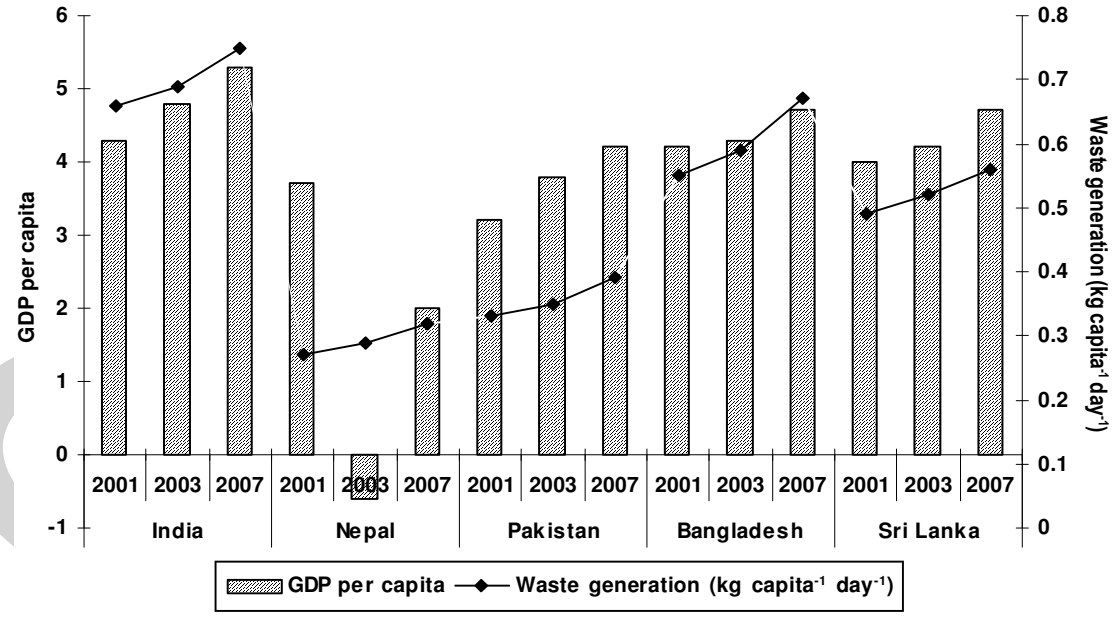

Fig. 2: Relationship between GDP per capita and waste generation of studied countries in 2001-2007. Source: (World Bank, 2003), (World Fact sheet, 2001)

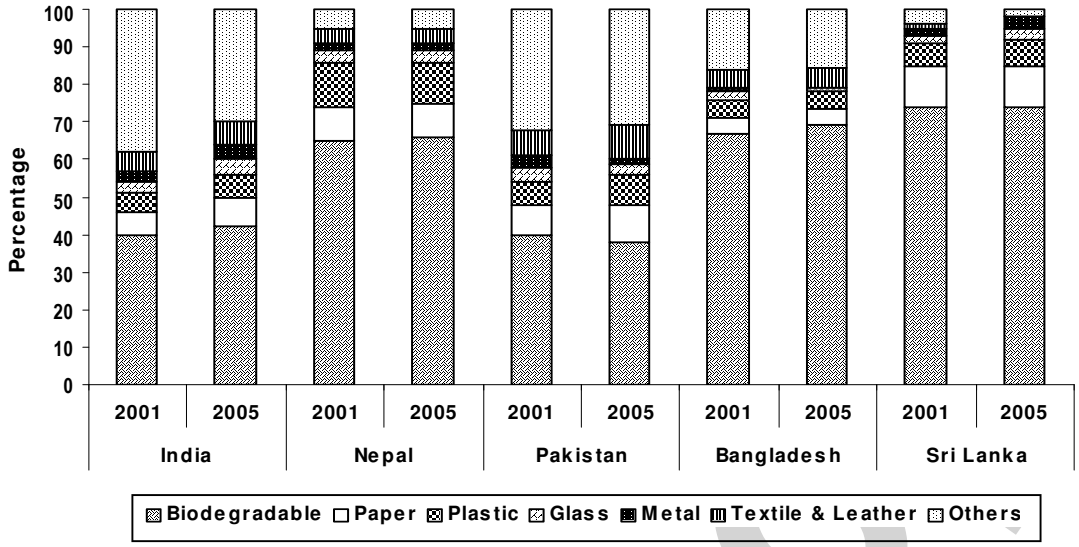

Fig. 3: Composition of municipal solid waste in studied countries. Source: (UNEP, 2001)

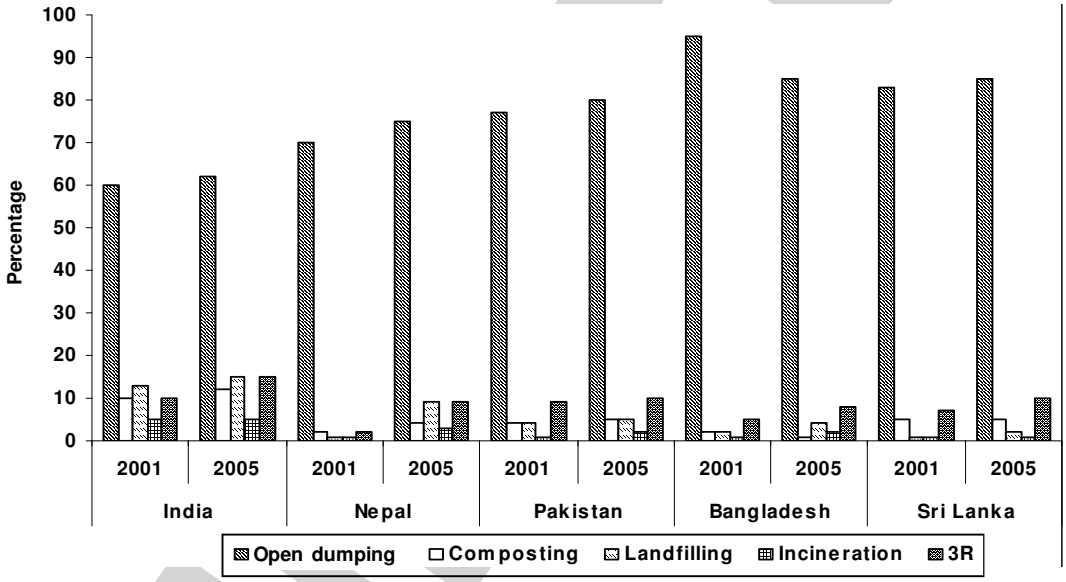

Fig. 4: Disposal method of municipal solid waste in studied countries. Source: (UNEP, 2001)

depending on lifestyle, food habits, standard of living, and degree of commercial and industrial activity. The level of waste generation goes to be higher up due to increase of consumption pattern as well as the movement of the people from rural area to urban areas. Municipal solid waste generation is also highly correlated with the economic growth *i.e.* Gross Domestic Product per Capita (GDP per Capita) (Table 2).

With respect of GDP per Capita, India will increase by 5.3 to 7% in predicated future but Nepal shows negative in previous years, because of the Moist insurgency, during 2003, averaged GDP per capita is less than negative 0.66, (Central Bureau of Statistics, 2007) (Table 2). This shows that the economic wealth is highly correlated with the municipal solid waste generation. The increasing rate of economic development may cause the higher quantity of municipal solid waste generation per capita per day.

Municipal solid waste composition: The complex composition of municipal solid waste (Fig. 3), reflects the heterogeneity of the waste stream. Most of the developing countries have high percentage (40-70%) of organic matter with high moisture content, which make them unsuitable for incineration (Agumuthu *et al.,* 2007). The considerable differences may be observed not only between countries but also between neighboring localities. Waste composition generated in studied countries, is normally dominated by biodegradable waste followed by paper and plastic waste.

Municipal solid waste treatment technology:

Open dumping: Open dumping is an illegal process, in which any type of the waste such as household trash, garbage, tires, demolition/ construction waste, metal or any other material dump at any location like along the roadside, vacant lots on public or private property even in parks other than a permitted landfill or facility. Open dumping

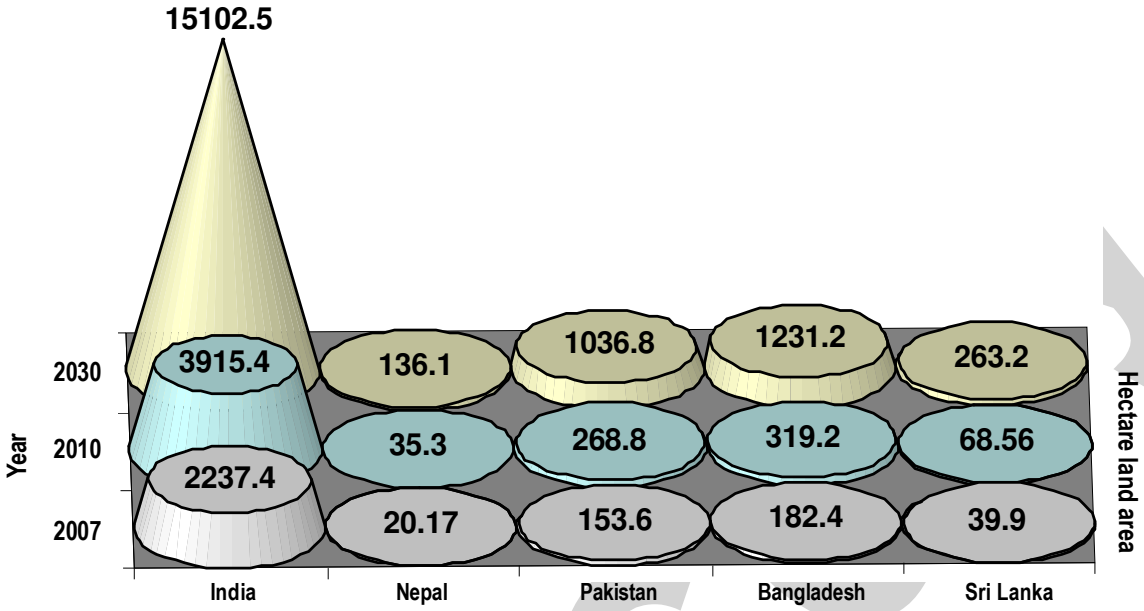

Fig. 5: Estimated land area for landfill disposal of studied countries. Source: (Gerard, 1998)

poses a threat to human health and the environment because it causes land pollution (Zurbrugg, 1999). Open dumping is distinguished from the sanitary land filling.

In the developing countries, municipal solid waste is commonly disposed off by discharge the waste in open dumps around 60-90% (Fig. 4), which are environmentally unsafe. Open dumping of non-degradable component like burning of plastic waste is added to create air pollution and uncollected waste pose serious health hazards. As a result of illegal dumping, land area such as property value may decrease and also put negative impact on the scarcity of land in future.

Composting: Composting is a natural biological process that carried out under controlled aerobic (requires oxygen) or anaerobic conditions (without oxygen). Organic waste is biodegradable and can be processed in the presence of oxygen or in the absence of oxygen using anaerobic digestion. Anaerobic composting is not common because of the slow degradation rate and produce odorous intermediate product. Anaerobic digestion however also produces methane gas which is an important source of bio-energy (Renbi and Sutanto, 2002).

In India, composting is used around 10-12% respectively (Fig. 4) because composting needs segregation of waste and sorting is not widely practiced. Relatively, composting is an efficient method to break down organic materials into an end product which is beneficial for soil and plants. Compost is used as an organic amendment to improve the physical, chemical and biological properties of soil. Adding compost helps to increase the ability of the soil to hold and release essential nutrients.

Landfill: Open landfill, is most common in developing countries. The so-called landfill is mostly covering by refuse waste in the dumpsite neither with proper technical input nor with treatment of the emerging emission to water, air and soil. In developing countries, such land filling is common for example around 15% of municipal solid waste goes to landfill in India and 9% in Nepal, respectively (Fig. 4). Although uncontrolled or open landfill is a perpetual pervasive problem which that can be a causes potential on human health hazards; and can, cause damage to vegetation damage, unpleasant odors, ground water pollution, air pollution and global warming (Mutasem *et al.,* 1997). Semi-controlled landfill, in which landfill operated at designated site, but every kind of municipal solid waste is dumped without segregation. It is not engineered to manage the emissions of landfill gases. Sanitary landfill, which is most practiced in developed countries with facilities for the interception of the leachate generation and also managed for the control of gases from waste decomposition.

Incineration: Incineration is one of the waste treatment technologies that involve the combustion of organic materials and other substances. Incineration waste treatment system is described as 'thermal treatment'. Incinerator process converts the waste into bottom ash, particulates and heat, which can be used to generate the electric power. The volume of ash is usually 10% of the original volume of the waste (Dhussa and Varshney, 2000). Finally, the ash is typically disposed off in the landfill site. In developing countries, the use of incineration is in few amounts to around 1-5% respectively (Fig. 4). Incineration is also a controversial method of waste disposal due to issue of cost and emission of gaseous pollutants.

3 Rs (Reuse-Recycle-Reduce): Recycling is resource conservation activity and it may offer a greater return for many product in energy saving. The recyclable materials such as paper, plastic and metal are often collected at the source. After collection, these items are sent to factories for recycling (Shapkota *et al.,* 2006). But in studied developing countries, recycling percentage is very

low around 10-15% (Fig. 4) due to the inadequate and insufficient source segregation.

Important accomplishment on sanitary landfill area: After all the treatment technology option for municipal solid waste, sanitary land filling is the final and ultimate disposal method of municipal solid waste. Landfill have served as ultimate waste receptors for municipal refuse, industrial or agricultural residue, wastewater sludge, incinerator ash, recycle discards, and/or treated hazardous waste. The sanitary landfill has proved to be the most economical and acceptable method for disposal (Khajuria *et al.,* 2008). A sanitary landfill is a carefully constructed space on the ground to store waste, as it gradually breaks down into chemically inactive material. The landfill is filled by the garbage and its also covered by clean layer of soil. These actions make landfill a safe place to bury garbage but in future, such waste disposal will demand a wide large land area for landfill disposal purpose. Land is considered greatest among the other natural resources. This estimates that with further generation of municipal solid waste in developing countries it would be necessary will lead to use much large area for waste disposal. Part of the landfill can be established in increase use of marginal land but the area required will be so large that and also there is no availability of land for crop land will be used for the purpose influencing crop production in these developing countries. In this way, in future it create crisis, due to scarcity of land space (Fig. 5).

On the basis of above study we indicate that, rapid urbanization and industrialization has caused tremendous increase of municipal solid waste generation in developing countries. With rapid development of economy and change of living standard, waste composition is expected to change. In developing countries, municipal solid waste is still collected without segregation and treatment facilities are also very limited. The proper disposal of municipal solid waste is a necessary step, to minimize the environmental health impacts and degradation of land resources. Illegal open dumping is most common practice for disposal of waste. Incineration will not be viable disposal option in the near future for developing countries because of its capital cost, high maintenance and installation cost and also the generation of high moisture content of municipal solid waste stream. The present study also indicated that much larger land areas need to be used for landfill shortage of natural resources such as land because the municipal solid waste generation will be increase. Therefore, this create a lot of problems in future, so we suggested and strongly recommended 3R technologies can be used which helps to minimize the problems associated with the generation and safe disposal practices of municipal solid waste. In this way, we save our productive land area and further it will be environmentally acceptable.

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