Kathmandu University
Journal of Science, Engineering and Technology

A review of comparative study on solid waste management practices in four different cities in Asian countries

Bikash Adhikari* and Samikshya Paudel

Department of Environmental Science and Engineering, Kathmandu University, Dhulikhel, Kavre, Nepal

Abstract

Waste Management is a grass root level problem and a decentralized and interdisciplinary approach is required to solve this problem. The exponentially growing population and the fast changing socio-cultural behaviors of humans influencing mass production and consumption rates are not environmentally sustainable and this explicitly defines the big picture in solid waste management scenario. The emerging threat to the world is not only the alarming growth in production of waste but also the unabating mismanagement of the waste we produce. This menace is troubling urban areas of both the developing and the developed nations with high population densities as the waste management is often practiced as putting wastes away from immediate sight. After reviewing a few papers about the solid waste management practices around the world, it intrigued me to write how the best practices differ from the worst practices in waste management around Asian cities. In this paper, we assess solid waste management scenarios around four Asian cities and throw a light on the management practices that best ones are doing differently to create a more sustainable urban environment for the residents. The countries who invest in holistic evaluation of waste produced by their citizens and conduct proper research on how to manage wastes by utilizing locally available resources seem to perform better in waste management sector.

Keywords: Best scenario; Waste management; Infrastructure development; Waste minimization

1. Introduction

The term 'solid waste' usually refers to the discarded materials from households, industrial processes, and commercial market as well as construction and demolition practices. Solid Waste Management therefore signifies management and disposal of the wastes arising from anthropogenic activities so that health and lifestyle of human beings are not affected. Toxic wastes find their ways from open dumps to the remotest areas of oceans from the network of rivers along human settlements and have become a major threat to a sustainable future of humankind. It has been estimated that if this trend continues, by 2050, we will have more plastics in the ocean (by weight) than the fish [1]. Such a serious concern, however, has not been taken seriously in many places around the globe. This inefficiency clearly indicates weak implementation of national level policies concerning management and proper disposal of wastes. This inefficiency in handling our own wastes is not only costing humankind aesthetic values but also causing biodiversity loses; human lives are at risk. Estimating and solving these problems have become increasingly complex because these pollutants have both point and non-point sources for mixing with and contaminating the environment. This situation further worsens the odds of finding one purposeful solution that would help the whole world. Given that multiple aspects like technical, socio-cultural, economical, ecological and political aspects are incorporated into solid waste management issue, the issue requires a multidimensional approach to find relevant solutions.

Urban and semi-urban areas are densely populated, and the trend to leave villages to live in big cities with more services and opportunities seems to be increasing day by day all across the globe. Wastes are the by-product of our lifestyle choices, increasing affluence and urbanization happening at an alarming rate across the globe. If we do not make conscious changes to our lifestyle choices, humans are set to increase waste production at the rate of 2.2 billion tonnes per year by 2025 [2]. The type and composition of wastes generated by population varies with respect to the distribution of resources. In high income countries, there seems to be more production of non-organic waste products due to more use of packaged materials, whereas in low income countries, organic waste seems to comprise a huge part of Municipal Solid Wastes (MSW). No matter what kind of management practices are employed around different cities in the world, we have yet to research and land on the perfect approach for solving this issue. For now, we can only analyze which methods are better than others.

Four cities were selected while conducting the assessment of waste management practices in this paper: Kathmandu, the capital city and the most densely populated city of Nepal, a developing country; Delhi, the capital city and most densely populated city of India with rapid industrialization going on for the last couple of decades; Seoul, the capital and the largest city of The republic of Korea, having the best waste management practices in the world; and Beijing, the capital of China, the emerging industrial hub of the world. Running a search across Google Scholar using keywords mentioned in 'Key Words' resulted in about 240,000 papers about solid waste management practices and the most recent papers available (preferably published after 2010 AD) were prioritized during the review process.

From these papers, we analyzed the factors that are identified to play an important role in proper management of solid wastes and examined the cities and areas with a good waste management system done differently than the other places. The finding of the study is anticipated to contribute in understanding how towns and cities can develop a wholesome and integrated model for the kind

*Corresponding author. Email: bikashadhikari@ku.edu.np

of wastes that they produce.

1.1. Kathmandu, Nepal

Kathmandu is the most urbanized city in Nepal. With an area of 50.76 km^2 [3], Kathmandu Metropolitan City currently has a population of 2.5 million people [4]. From 2001 to 2011, Nepal's population increased by 1.35% per annum, while Kathmandu's urban population grew by 4.78% [4]. The average waste generation rate of Kathmandu Metropolitan City is 0.66 kg per capita per day [5]. This report also took into account dirt and construction debris, the uncollected wastes along sidewalks and streets, in corners and in any vacant land.

Household waste is found to constitute 50 % to 75 % of Municipal Solid Waste [7]. The household wastes is composed of organic wastes at largest portion (60.5 %) followed by Plastics (9 %), paper and paper products (11 %), textiles (3%), wood (2.5 %), construction debris (4 %), glass (1.5 %), metals (3 %) and other wastes (5.5%) [6]. Biodegradable wastes can be used to make compost and fertilizers but they are being mixed with other non-biodegradable wastes, causing methane gas to mix in the atmosphere as a consequence of anaerobic digestion, and leachates to pill from waste dumps and seep into groundwater tables intoxicating water resources.

The main problem of the city in Solid waste management is open dumping of solid wastes in public places and alongside rivers and streams. Collection of wastes is done through door to door collection methods, roadside pickup from open piles and roadside container collection. Collection efficiency is 86.9 % [7], which however, does not reflect the sight of the urban poor areas. The high market areas and posh neighborhoods of Kathmandu Metropolitan City are for sure cleaned and swept but in the areas where poor people live in temporary homes like the neighborhoods along Bagmati riverside, open dumping is quite a common site. Kathmandu Municipality allocated as much as 26.72% of total municipal budget on Solid Waste Management during 2011 AD but most of this budget (60% to 70%) was spent on collection of wastes and street sweeping and 20% to 30% was spent on transport of wastes leaving little to no budget for proper disposal of wastes [7].

The fact that there is only one compost plant in a context where 60.5% [6] of the waste is bio-degradable organics reflects technical and managerial incompetency in the waste management sector. With commercial and industrial activities increasing at an exponential rate in this city, crude dumping sites are also increasing exponentially and the proportion of waste disposed to sanitary landfills is about 95% [6] which could easily be reduced to about 10% [7] if proper resource recovery methods are applied to the wastes. This dumping is also not done in a sanitary manner and thus, there are frequent local protests about the nuisance caused by landfill sites which are termed 'sanitary landfill sites' but are more like large open dumping area without proper landfill liners, leachate control mechanisms, gas control and collection, surface water drainage, final cover soil, compaction and environmental monitoring facilities.

Currently, there are more than 1,111 people working on waste management sector on a regular basis in Kathmandu city and more so informally [8]. Most of the segregation works are done by informal workers or rag pickers for their livelihood by collecting and selling high-value recyclable materials to vendors. The process is labor intensive and working conditions are quite unsafe and on top of that, these workers are working for exceptionally low incomes. It is evident that this situation is a result of unstable political situation and lack of clear policy and legislation. Little to no capacity building workshops is being held for the workers in Solid Waste Management. There is no availability of required investment in the waste management sector and this could be because it does not seem to promise a good yield in return of investments. This occurs because there is no culture of segregating wastes at the source which makes the whole resource recovery method labor intensive and expensive. Therefore, segregating wastes at the sources and basic awareness among public about how to separate their 'wet' wastes from their 'dry' wastes is going to be a big stepping stone towards sustainable waste management. The nation's inadequacy to monitor and ameliorate inefficient or ineffective bureaucracies, lack of adequate regulatory and enforcement tools, corruption, lack of will to enforce regulations or absorb cost of mitigation, and lack of basic understanding of impacts and risks also play important roles in this incompetence of waste management sector in Kathmandu Metropolitan City.

A scenario analysis for solid waste in Kathmandu city was conducted in 2014 by Singh [9] on the basis of Global Warming Potential, Biochemical Oxygen Demand, final disposal of waste, recycling levels and energy recovery. The paper concluded that small technical changes such as collecting methane gas produced by the wastes, collecting and treating leachate can make a huge difference in improving the whole waste management system. Socio-cultural and policy level changes such as formalization of informal waste pickers and segregators by local government to separate recyclable waste, encouraging local people to separate their organic waste would add to the improvement of waste management system. Also, treatment of wastes by methods like compost or bio gasify them for fertilizers and electricity and appropriate management of existing sanitary landfills can make a great deal of environmental and socio-economic benefits to the people residing in Kathmandu city. The paper emphasizes the importance of cooperation among stakeholders and promotion of resource recovery methods in the city [9].

1.2. Delhi, India

The national capital city of Delhi is one of the fastest growing cities in India. The population density of Delhi was 274 people/km^2 in 1901 which increased to 1,176 people/km^2 in 1951 and further to 9,294 people/km^2 in 2001 [10]. This mega-city has an area of 1483 km^2 and an official population approaching 14 million with a population growth rate of 1.5 % in 2006 [11]. The solid waste production of this city is roughly 0.57 kg per person per day which is more than many other Indian cities [2].

The solid waste management of city of Delhi is currently being carried out by three local bodies namely, Municipal Corporation of Delhi (MCD), New Delhi Municipal Corporation (NDMC) and Delhi Cantonment Board (DCB). The population in Delhi does not pay collection and disposal fees separately but they pay the fees along with property tax. The solid wastes in Delhi comprises of 38.60 % of organic wastes, 5.6 % of paper, 6 % of plastics, 2 % of metals, 1 % of Glass and 46.8 % of other wastes [10]. The main problems of solid waste in Delhi are pollution and open dumping in urban poor neighborhoods and markets followed by inefficient disposal of wastes in dumping sites.

This city usually collects and dumps up wastes that are heterogeneous in nature. However, there is an increasing culture of segregation of wastes at source as a response to the public awareness and participatory programs conducted by the government in local areas. The city has an average collection efficiency of 75 % with controlled disposal of 87 % [11].This collection efficiency generally responds to the richer neighborhoods of city which, with respect to their higher tax yields, are served first and there certainly is disparity when it comes to managing waste for the poor. The rich citizens who have more political and monetary power at their disposal can easily avoid or opt out of direct environmental impacts of solid waste pollution in the city by shifting their pollution towards more unfortunate citizens. The open dumps in these urban poor neighborhoods also act as breeding grounds for disease vectors adding to the vulnerability of its residents.

A total of three mechanical composting plants are in operation in Delhi, eight dumpsites have been exhausted so far by dumping of MSW and three dumpsites are in operation. The area covered by these dumpsites is estimated to be at least 1 % (14.83 km^2) of Delhi's total area making the unavailability of land for disposal of wastes a rising problem for MSW treatment in Delhi. In response to this issue, local bodies make a blunder of disposing wastes in open dumps at low-lying areas of city, converting them into open dump hills which further worsen the situation. It was estimated that the active and closed dumpsites produce approximately 81.5 million litres of leachate annually, most of which go untreated and end up in groundwater by percolation [10].These landfill sites lie in periphery of river Yamuna which is responsible for 70% of the water supplied to people living in Delhi [12].

A total of 33% of waste generated is recycled where 27% of the recycling is done by the informal workers. They pick up and sort recyclables from mixed waste either at central waste collection bins or dumping sites. There are a total of 170,000 informal workers responsible for recycling of solid wastes which suggests that these informal workers make up to 1.2% of the total population of Delhi and the waste they help recover sums up to an average of 5 tonnes per worker per year [11]. These workers save the government approximately INR. 600,000 (USD $13,700) daily in segregation and transport of recyclables [13]. If the undervalued works of waste pickers are recognized by the local government at a level by providing them with safe working conditions and a decent payment, it would also aid in uplifting the living standards of these workers and their families.

Typical institutional deficiencies are seen in solid waste management sector in Delhi and its formal workers faced by many urban local bodies in developing countries. "In the Municipal Corporation of Delhi, there are about 46,000 workers in solid waste management but only 33,000 are available in the field. The absentee rate is 25%. The rest serve as domestic servants at the residences of politicians. The sanitary inspector, who supervises them, knows about it but is easily bribed to mark him as present" [14]. This statement clearly represents how some population is taking their job for granted by not obeying and respecting the system while other unfortunates have to work informally.

To say that Delhi does not have laws and policies that promote efficient management of solid wastes in the city would be wrong. The problem is with poor maintenance of existing infrastructures and lack of monitoring by government officials. An incinerator was bought and operated in Delhi during the 1980s and was expected to generate power to supply for local grids. But, operational experience was not satisfactory [15]. This reflects the kind of mistake cities like Delhi have been making; little to no research on which waste disposal methods would work best for the types of waste, socio-cultural environment as well as financial situation of their place have been carried out. Lack of segregation, poor maintenance and route planning during transportation stage, no socio-environmental criteria to be fulfilled for landfilling, poor maintenance of landfill sites in collection and treatment of methane gas or leachates and no institutional coherence all aid to an inefficient solid waste management and disposal system in Delhi. However, Delhi plans to treat 42% of generated waste by 2024 by taking certain steps like privatization of MSW collection, segregation, transport and disposal, public sector, private sector and citizens working in coherence by promoting involvement of local communities and NGOs in raising public awareness and participation, working in proper identification of applicable MSW technologies like anaerobic digestion and bio-methanation, regulating and optimizing the performance of plants [12]. Delhi has already managed to attract international investment to assist with developing state-of-the-art facilities and will hopefully make more efforts to reach to its goals within 2024.

1.3. Seoul, Korea

Politically, The Republic of Korea is divided into nine provinces and seven metropolitan cities including the capital city, Seoul. Seoul city has a population density of 481 people/km^2 which ranks to be the third highest in the world [16]. The national capital, Seoul, has a population of about ten million people and the total urban population in 2010 was 82% of total. Seoul's 10.3 million residents in 25 districts generated 11,170 tonnes/day (t/d, i.e., 4077 thousand tonnes per year) of municipal solid waste (MSW) in 2005 [17].

The waste in Korea comprises of Paper (35.1%), Plastic (21.4%), Food (8.1%), Wood (1.6%), Rubber (0.9%), Leather (0.4%), Fabric (0.4 %) and others (32.1 %) [18]. Since the early 2000s, the Republic of Korea has maintained top-rank status for its municipal solid waste (MSW) recycling rate among OECD (Organization for Economic Co-operation and Development) member countries. The most recent 2014 OECD MSW data show that the MSW recycling rates of the top-three countries were 58.1% (South Korea), 47.6% (Germany), and 33.8% (Belgium). Thus, South Korea exhibits an outstanding MSW recycling rate even among the top-tier members [2]. Until the mid-1990's, 'collection and landfilling' was the traditional method of Solid Waste Management in Korea. But it was not very effective so Government of Korea introduced several market-based policies and systems that helped in shifting their Waste management worries to emission of less GHG, producing more jobs and increasing resource recovery and some of them which made a huge shift in the waste management system are discussed in this paper.

The total amount of municipal waste generation was 83,962 tons/day in 1990, and 58,118 tons/day in 1994. About 93 percent of solid wastes was dumped into the landfills in 1990. Until 1994, a waste tariff system in Korea was set up as a monthly lump-sum fee system where each household made a fixed amount of payment for waste management services. In 1995, Korean Ministry of Environment (KMOE) introduced the Volume Based Waste Fee (VBWF) system [19] to impose waste treatment costs on each polluter according to the amount of waste disposed by them. By providing free collection for recyclable waste, this system induced the public to be more active in waste separation at the source. After the implementation of the VBWF system in 1995, the MSW generation fell from 58,118 tons/day in 1994 to 47,774 tons/day in 1995 showing a 18% reduction and the recycling rate increased by 27% compared to the previous year, 1994 [20]. Between 1994 and 2004, MSW generation decreased by 14 % and the recycling rate increased by 34%. The landfill rate drastically fell from 81% to 16%. Waste generation per capita also dropped from 1.33 kg/capita/day in 1994 to 0.95 kg/capita/day in 2011. VBWF without question proved to be one of the best policies in the history of waste management in Korea.

"Extended Producer Responsibility" (EPR) system was introduced in January 2003 after the failure of 'deposit-refund' system. This system improvement was driven by some key ideas; recycling initiatives should drive the economy as there was less space for landfill due to increasing population. Korea's compliance with international regulations and agreements like EU ROHS (Restrictions on Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment) was prioritized. The problem of resource scarcity: both resource depletion and the increasing price of resources had to be addressed as soon as possible. If producers or importers did not fulfill the mandatory recycling rates, a fine was imposed. This fine is calculated based on the recycling shortfall multiplied by 115 to 130 percent of the standard recycling cost calculated by the Korean Ministry of Environment. The EPR system also proved to be one of the best systems introduced in waste management sector. Major achievements of the EPR system include

increased recycling of waste and optimization of resources. The mandatory rate for the EPR products has been continuously increasing even though the actual recycling amount and rate did not initially meet expectations. According to the K-eco, comprehensive recycling performance has been meeting the target since the introduction of EPR system. However, the performance rates for each item varied from 50% (silver oxide batteries) to 117% (plastic packaging materials) in 2014.

Every year in Korea, 26 million vouchers (83 tons of mail) were used with an estimated cost of 1 billion USD to fill out the details of waste produced and disposed at the waste management facilities [21]. These documents were inconvenient to track illegal dumping which was the main purpose of this document. Therefore, Allbaro (e-manifest) system was introduced by the KMOE in 2001 to replace the hectic and conventional system. It allows for the entire waste management and disposal process to be accessed and monitored in real-time online and thus, has a function to prevent illegal waste treatment and disposal.This system has helped in reducing the burden of management and costs by digitization, improving transparency levels with the public which in turn built up awareness and trust among the public on the waste management system. It stores information on waste management ranging from generation to final disposal including detailed information of waste generators, transporters, and disposers. Allbaro has been recognized as an innovative Korean brand, and has been patented through the Korea Intellectual Property Office (KIPO). It is estimated that KRW 134 billion (about USD 122 million) and 9.8 million hours of time has been saved annually after the introduction of Allbaro system [22].

Korea MOE released "Guideline of the 3rd Solid Waste Management Plan" to local governments in February 2011. The 3rd Seoul Solid Waste Management Plan was established in early 2013. This is the latest plan set up the role for basic frame of SWM in Seoul for 10 years: from 2012 to 2021. Achievements during the 2nd Seoul SWMP (2002-2011) were evaluated by the government in terms of the performances of waste treatment methods and reduction of GHG emissions. This latestplan aims to achieve three policy stances: environmental conservation, environmental justice, and social sustainability. These policy stances give six policy directions i.e. direct landfill elimination, maximization of resource recovery, waste collection system for city sanitation, optimization strategy for waste facilities, improving waste treatment business, and improving waste governance. The goals of the 3rd Seoul SWMP are direct landfill 5.4 % and resource recovery 72 % by 2021. It is predicted that successful execution of the plan will reduce greenhouse gas emissions and increase jobs. GHG emission is targeted to be reduced by 9.8 %: from -4,061 thousand tons CO_2/year in 2009 to -4,459 thousand tons CO_2/year in 2021. It is estimated that GHG emission shall be -1.14 t CO_2/ton MSW in 2021. The number of jobs in waste management sector could be increased by 0.63 % from 11,102 thousand jobs in 2009 to 11,172 thousand jobs in 2021. It is estimated that the number of jobs will be increased in the field of material recovery of wood waste and recyclables and incineration whereas reduced in the field of recycling of food wastes and landfilling. The numbers of jobs are set to be 2.86 jobs per ton MSW in 2021 [23]. Table 1 illustrates the past data and interpolation of the past data to approximate future data as achievable targets for greenhouse gas emission and job creation due to these strategic policy changes.

The statistical indicators of greatest achievements of these strategic policies and systems have been good performances of waste treatment methods and GHG reduction effects. However, waste management attitudes, age, and income have been seen to influence recycling and waste management behaviors in Koreans. A possibility is that proper and efficient recycling and waste management behavior is mostly influenced by people's motivation to avoid the cost for waste disposal and not due to an eco-friendly awareness and/or attitude [24]. Whatever the reason is, statistics show that these policies are bringing a positive change among Koreans. The expansion of the number and functions of recycling facilities in Seoul can be considered the key component of success. Incineration plants are run in different local governments which help to reduce GHG rates. Waste incineration plants are partially used in Seoul, which resulted significant increase of operation rate from 31 % in 2005 to 82 % in 2010 and 85 % in 2012. Additionally, four incineration plants recovered heat energy of 461 thousand Gcal in 2005 and 1,761 thousand Gcal in 2010. As a result, the incineration amount was increased from 416 to 723 thousand tons of waste and Landfill decreased from 1,038 to 528 thousand tons of waste in 2005 and 2010 respectively which shows a 50% decrease in landfilling of wastes [23]. Therefore, resource sharing, public campaigns in making Seoul plastic free and a good foster seen in zero waste communities in Seoul are the positive changes happening in public attitude towards waste management in Seoul [25].

1.4. Beijing, China

Beijing, the capital city of China with the land area of approximately 1368.32 km^2, is located at the tip of the North China plain. The city inhibited an urban population of 13.3 million people in 2006 with an annual increase of 3.54%. The average MSW generation rate in 2006 was 0.85 kg/capita/day or 4.134 million tons/year in the metropolis [26].

The MSW in Beijing mainly contains food waste (63.39 %), followed by paper (11.07 %), plastics (12.7 %), construction debris (0.62 %), dust (5.87 %), wood (1.78 %), glass (1.76 %), textile (2.46 %), metal (0.27 %) and other wastes (0.08 %) [27]. Given a large composition of food waste in MSW, its management has primarily focused on reduction of wastes and resource conservation with the aim of gradually substituting sanitary landfill by incineration and composting. For this, proper management of food wastes is a crucial step and Beijing addresses this problem by separating wastes at the source.

Beijing has a MSW collection rate of 96.5% where 52% of wastes are collected separately at the source. According to corresponding statistics, 90% of MSW generated in Beijing was landfilled, 8% was incinerated and 2% was composted in 2006 [28]. About 4.7 million people in Beijing separated their wet and dry wastes during the time of initial disposal at the end of 2007 and this method has proved to solve one of the main issues of waste management in the city since incineration is considered the preferred technology and the authorities have a plan on sky rocketing the percentage of incineration of wastes to 30% in the near future [28].

The Municipal Solid Waste characteristics of Beijing are combustible waste (91.51 %), compostable waste (77.08 %), moisture content (61.21 %), recyclable waste (25.18 %); and the waste had a low calorific value (4564 kJ/kg) [27] The low calorific value and high moisture content of MSW indicated that even though combustible waste accounted for 91.51 % of total waste in 2006, the waste could not be incinerated efficiently without additional support [29]. Furthermore, the electricity that powers Beijing city is non-clean energy derived from coal and there is a negligible change in the environmental impact potential of the waste whether they are treated by disposal in sanitary landfills or by incineration methods [30].

The main treatment and disposal technology of wastes in Beijing city is thus sanitary landfilling followed by incineration of wastes. The first sanitary landfill site (Asuwei Landfill Site) was established in Beijing in 1994 and in 2006. There are a total of 13 landfill sites and four incineration/composting plants in Beijing City, which corresponds a total designed capacity of 10350 tons/day while the approximate waste generation rate in Beijing City is 11326 tons/day. Also, there are six transfer stations in Beijing that compress and

Table 1: Greenhouse gas emission and job creation data corresponding to the third Seoul SWMP [23].

Category	Year					GHG emission factor (ton-CO_2 /ton waste)	Job creation factor	
	2009	2012	2015	2018	2021		Collection jobs (Jobs/ton-waste)	Facility (Jobs/ thousand ton-waste)
Waste to collect (t/day)	11,337	11,010	10,768	10,732	10,697			
Wood waste recycling			161	163	167	-2.46	2.2	4.3
Recyclables recycling	4,149	4,360	4,211	4,248	4,283	-2.87	1.5	2.9
Food waste recycling	3,446	3,347	3,273	3,263	3,252	-2.00	1.3	0.6
Incineration	2,041	2,092	2,434	2,425	2,417	0.37	1.3	0.2
Direct landfill	1,701	1,211	689	633	578	0.42	1.3	0.2
Greenhouse gas emission								
Annual emission(thousand ton-CO_2/ year)	-4,061	-4,343	-4,360	-4,410	-4,459			
Unit rate (ton-CO_2/ton-waste)	-0.98	-1.08	-1.11	-1.13	-1.14			
Job creation								
Annual Job creation (Jobs/year)	11,102	11,132	11,127	11,148	11,172			
Unit rate (Job/thousand ton-waste)	2.68	2.77	2.83	2.85	2.86			

separate wastes to ensure efficiency in transportation and recycling rates. Out of these stations, only two have the required sorting machinery well equipped and thus, they have limited sorting rate of 980 tons/ day. These figures clearly indicate a considerable gap between the designed capacity, required investments and infrastructures, the waste efficiently managed and waste generation rate. This has led to infer that almost all the landfill sites, transfer stations and treatment plants are overwhelmed with waste management practices [29].

Approximately 1.638 million tons of materials were estimated to be recycled in 2006 which is 7.3% higher than in 2005. This figure roughly includes 0.868 million tons of metals, 0.364 million tons of paper, 0.168 tons of plastic and 0.077 million tons of glasses. This data definitely shows that recycling does not happen in its full potential and thus the trend of recycling wastes and creating a waste value chain is rising culture in Beijing. It was also seen that recycling focuses on high-value materials and neglects low-value materials which is a long-term issue. It was estimated that Beijing saved approximately USD 1.43 million through formal recycling sector in 2006. There is also a huge culture of recycling across the informal waste management sectors in Beijing. It was estimated that in 2006, there were as much as 300 thousand individuals making a living as informal recyclers or waste pickers, contributing to recycled materials that worth USD 0.438 million annually [29].

The main strategies that Beijing needs to work on shall be pollution control during the waste management process i.e. evolving whole waste management system using appropriate technology. Waste management sector needs more investment to further expand the capacities of transfer stations and treatment plants because if this problem is not addressed in the very near future, given the population growth rate and waste generation rate, the situation might get too bad too soon. If the technological advancement that we see on other sectors would also resonate with the waste management sector, Beijing can do wonders given their budget and other immediate resources at the country's disposal. Another issue that needs to be addressed is the one regarding informally working recyclers or waste pickers. If these undervalued individuals are ensured of better working conditions and their efforts are recognized properly, Beijing could provide a better life to about 300,000 individuals and their families.

2. Discussion

Table 2 summarizes the information that has been presented in this paper. Comparison of important indicators have been done to reflect on the current status of Municipal Solid Waste Management systems of these cities.

Here, we can see that the collection efficiency of Kathmandu and Delhi are at a very similar range as these cities are more similar in socio-cultural, economical, and awareness aspects compared to the other two. They are the capital cities of developing countries while Seoul and Beijing are the capital cities of emerging economies of the world. Thus, the collection efficiencies of Seoul and Beijing are also in a similar range. However, when it comes to the wastes that are landfilled, Seoul is at 5.4%; Delhi is at 45%; Beijing is at 90%; and Kathmandu is at 95 %. This data indicates how recycling and resource recovery methods are implemented in each city. The city where resource recovery methods are not properly implemented dumps all of its wastes to sanitary landfills without calculating how wastes could be used as valuable resources. In cities like Delhi and Kathmandu where these sanitary landfills are not maintained efficiently, the landfills can rather be called as open dumps. Similarly, cities of the developing world seem to have a larger fraction of organic waste in their waste stream. This can be because segregation of wastes is not a culture rooted among the public. The composition of plastics and paper wastes seem to be high in places that are more industrialized compared to others. Also, the main issue that most of the cities have in common seems to be improper management of informal workers who contribute to the waste management sector.

Table 2: Comparison of status of MSW management in the four cities.

	Kathmandu, Nepal	Delhi, India	Seoul, Korea	Beijing, China
Collection efficiency	86.9%	75%	100%	96.5%
Waste that goes into landfills	95%	45%	5.4%	90%
Proper maintenance of sanitary landfills	No	No	Yes	Yes
Methods used for resource and energy recovery	Recycling of wastes mostly by informal workers.	Recycling of wastes mostly by informal workers.	Well managed recycling, Well managed incineration	Source separation during collection (52%), Landfill, Incineration.
Status of solid waste management.	Poor	Poor	Best	Good but needs more investment
Main concerns for solid waste management in the most immediate future	- Poor maintenance of dumping sites - Institutional deficiencies - Public awareness	- Open dumping - Poor maintenance of dumping sites - Institutional deficiencies - Poor working conditions for a large group of informal workers - Public awareness	- GHG emissions - Energy recovery - Discarding use of non-biodegradables	- Energy recovery - Existing resources are overwhelmed, waste management sector needs more investment - Consideration of environmental impacts of different waste management methods.

For a reduced global foot print and a sustainable future for mankind, empowering local bodies for efficiency in waste management system is necessary. Each city has its own waste characteristics and socio-cultural values, this is seen to vary with industrialization and wealth. Motivation and emphasis for in-situ management of wastes in a certain place is always a good step. Another problem in solid waste management is untrained employees. Capacity building programs should be conducted and run such that sustainable and efficient framework and directions can be established with locally available technology and locally available human resources. This will also help address unemployment problems in poor countries as economic feasibility is an important factor for sustainability in waste management practices [31].This will also help reduce transportation costs to a certain extent. It is also seen that developing countries spend more than half of their waste management budget in collection and transportation and little to no budget is left when it comes to disposal and treatment. Investment opportunities for research and development thus are very sparse in developing countries that need them the most.

The immediate action that can be implemented should be management of wastes in open dumps. Proper solid waste management strategies shall be formed and implemented to contain pollution from traveling from landmass to water bodies. If improper disposal of wastes is not managed, the plastics are still going to end up in rivers and oceans and the aquatic wildlife will keep on paying for the harmful deeds we imposed upon the environment. Awareness programs targeting the general public about sustainable consumption, sorting out wastes from their household level, hazards of using micro beaded cosmetics, plastic shopping bags and straws, reduce, reuse and recycle shall be conducted at local levels. This shall help the public in taking accountability for the wastes they produce and make them more mindful about their disposal. Community based recycling activities and programs sound like a good idea but it would ideally only help to clean up our neighborhoods once. Local bodies should try to conduct life cycle assessment and track down the sources of pollution. Measures such as taking record and maintaining track of seasonal and geographical waste fluctuations should be tried. This data will help in research and development in the field of MSW management. Reward system can be implemented to institutions and citizens who promote sustainability in waste management. If this is done, a good amount of public attention can be drawn to building a sustainable waste management strategy.

Promotion of waste recycle business can be done by providing subsidies for these businesses: support by the government in areas like tax cuts or less interest rate on governmental loans would prove to be crucial. This would definitely attract investors towards waste recycling business. Use of analytical tools like the demand and supply curve in waste analysis can be done and the concept of 'Green economy' can be promoted by imposing less tax on the products that are made of sustainable materials and promote optimum utilization and conservation of earth resources. For this, first of all, researches related to waste management approaches such as energy recovery should be done. Unless there are lots of researches being conducted, we shall never know what shall work for us.

The policy for production of non-bio degradable materials should change in areas such as codes of conduct, smart packaging guidelines, supply chain reporting and compliance audits. These changes would definitely offer opportunities to improve management of issues regarding production and proper disposal of non-biodegradables. It is actually good if the public voluntarily gives up and discards materials that are toxic for the environment in the long run but for the time being, imposing tax on the retailers and consumers who use non-degradable like plastics could trigger them to discard using such products. When producing pellets and resins, use of identification codes can be encouraged so as the recycling process would be easier and this would also increase resource efficiency. The governments could put a "minimum recycled content requirements" for non-biodegradable products like plastics.

3. Conclusion

This paper indicates what it takes for solid waste management practices to be effective. The countries/cities that gave importance to research and holistic evaluation of waste produced by their respective city population had more efficient and sustainable waste management system. The management practices that yield best results are those that use a multidisciplinary approach.

Management of Municipal Solid Waste generally comes under the responsibility of local governments. Technical difficulties in collection, transport and disposal of waste, lack of awareness among public and unavailability of skilled human resources, economic barriers in researches and development of new technologies, traditional methods used in segregation of wastes by landfill scavengers, waste smuggling, high littering rates, illegal dumping of wastes, little to no knowledge about recycling of wastes and difficult local architecture for collection are some of the areas that are a clear indication of inefficient public services in developing countries. Also, fragmented governance affecting the accountability among stakeholders is playing a big role in these inefficiencies. If awareness among public in sustainable consumerism, segregation of wastes, recyclable/non-recyclable/hazardous wastes is spread, it could help in management of solid waste collection process to a level. But, for proper disposal, researches in how to utilize locally available resources and manpower, capacity building training programs for employees working in waste management sectors, research for appropriate energy recovery processes, establishing proper management frameworks like setting goals for the disposal and creating awareness for discarding the use of non-biodegradable materials can be a kick start to management of solid wastes in the local level.

The main inadequacy of the current waste management approach is that we do not have a sustainable waste management approach for our respective localities. Policies are formulated in National and Regional level but actions are to be taken at the local level: inclusion and participation of public is absolutely essential to bring changes in the system. The existing Solid Waste Management practices are economically unsustainable and require an unacceptable financial risk which is why investors might think it is a better idea to put their money into investment somewhere else, like the plastic industry which is responsible for majority of pollution but has great investment returns. Absence of technical and practical skills, weak infrastructure and inadequate technological advancements are some other problems to solid waste management in developing nations. Also, practical laws are not brought into action or, have insufficient interpretation and application on a daily basis. Policies and laws are made by bureaucrats who have strong alliance with big corporate houses and businessmen and they tend to trade loopholes in policies and laws with planetary sustainability. This kind of successful industry advocacy of insipid, business-friendly governance interventions under the guise of corporate sustainability, contributing to an overconfidence with the value of individual responsibility and corporate self-governance as management principles has been stern in maintaining their profits while sucking the life out of the planet [32]. In brief, there is a lack of holistic approaches or multi-dimensional approaches in the waste management systems around the world.

If waste management issues are addressed at the local level, figuring out what works and what does not through proper research, and the concerned stakeholders work accountably, we could minimize the disastrous situation we have been putting ourselves into.

References

[1] Ellen MacArthur Foundation, The New Plastics Economy - Catalysing action (2017).

[2] Hoornweg D & Bhada-Tata P, What a Waste: A Global Review of Solid Waste Management, World Bank (2012).

[3] Central Bureau of Statistics (CBS) of Nepal, Population Census 1991. Vol. 1, Kathmandu, Nepal: Central Bureau of Statistics (1991)

[4] Central Bureau of Statistics (CBS) Nepal, Population monograph of Nepal. Kathmandu, Nepal: Central Bureau of Statistics, http://dataforall.org/dashboard/nepalcensus/ (2012) .

[5] Dangi M, Pretz C, Urynowicz M, Gerow K & Reddy J M, Municipal solid waste generation in Kathmandu, Nepal. *Journal of environmental management*, 92 (2010) 240-9.10.1016/j.jenvman.2010.09.005.

[6] Adhikari B, *Physicochemical assessment of leachate and biogas generation potential in landfill sites of Nepal*, PhD dissertation, Kathmandu University, 2016.

[7] Asian Development Bank, Solid Waste Management in Nepal Current Status and Policy Recommendations (2013).

[8] Government of Nepal, Solid Waste Management of Kathmandu Metropolitan City Environment Audit Report (2015).

[9] Singh R, Yabar H, Mizunoya T, Higano Y & Rakwal R, Potential Benefits of Introducing Integrated Solid Waste Management Approach in Developing Countries: A Case Study in Kathmandu City, *Journal of Sustainable Development*, 7 (2014) 70-83.

[10] Srivastava, A & Nema A, Life Cycle Assessment of Integrated Solid Waste Management System of Delhi (2011).

[11] Wilson D C, Rodic L, Scheinberg A, Velis C A & Alabaster G, Comparative analysis of solid waste management in 20 cities, *Waste Management & Research*, 30(3) (2012) 237-254, https://doi.org/10.1177/0734242X12437569.

[12] Talyan V, Dahiya R P, Sreekrishnan T R, State of municipal solid waste management in Delhi, the capital of India. *Waste Manag.*, 28(7) (2008) 1276-1287, https://doi:10.1016/j.wasman.2007.05.017.

[13] Sharholy M, Ahmad K, Mahmood G & Trivedi R, Municipal solid waste management in Indian cities – A review, *Waste management*, 28 (2008) 459-67.

[14] Ahmed, K & Jamwal N., Garbage: your problem, *Down to Earth* (2000) 31, pp. 30-45.

[15] Narayana T, Municipal solid waste management in India: From waste disposal to recovery of resources? , *Waste Management*, 29(3) (2009) 1163-1166, https://doi:10.1016/j.wasman.2008.06.038.

[16] The Korean Ministry of Environment, Overview of policies & efforts (2006).

[17] Yi S, Yoo K.-Y, & Hanaki K, Characteristics of MSW and heat energy recovery between residential and commercial areas in Seoul, *Waste Management*, 31(3) (2011) 595–602,. https://doi.org/10.1016/j.wasman.2010.09.008.

[18] Bourtsalas A, Seo Y, Alam T & Seo Y-C, The status of waste management and waste to energy for district heating in South Korea, *Waste Management*, 85 (2019) 304-316.

[19] Park S, Factors influencing the recycling rate under the volume-based waste fee system in South Korea, *Waste Management*, 74 (2018) 43-51, https://doi.org/10.1016/j.wasman.2018.01.008.

[20] Korea Environmental Policy Bulletin, Volume-based Waste Fee System, KMOE (2003).

[21] Hyun Soo J, Korea Environmental Policy Bulletin, KMOE & KEI (2008).

[22] Sustainable Development Goals Policy Brief Series No.3: Comprehensive Study of Waste Management Policies & Practices in Korea and Recommendations for LDCs and MICs, UNDP (2017).

[23] Yoo K.-Y, & Yi S, Evaluation and development of solid waste management plan: A case of Seoul for past and future 10 years. *Journal of Material Cycles and Waste Management*, 17(4) (2015) 673–689. https://doi.org/10.1007/s10163-014-0294-2.

[24] Lee S & Paik H, Korean household waste management and recycling behavior, *Building and Environment*, 46 (2011) 1159-1166.

[25] Korea, Citizens at the center: Seoul's journey to zero waste https://zerowasteworld.org/wpcontent/uploads/Korea.pdf, April, 2020.

[26] BMBS, 2003-2007, Beijing Statistical Yearbook, Beijing Municipal Bureau of Statistics (2007).

[27] BMAC, 2006-2007, Beijing Environmental Sanitation Development Report, Beijing Municipal Administration Commission (2007).

[28] BMAC, 2007, Beijing "11th Five-Year Plan" Period Environmental and Sanitation Planning, Beijing Municipal Administration Commission (2007).

[29] Zhen-Shan L, Lei Y, Xiao-Yan Q & Yu-Mei S, Municipal solid waste management in Beijing City, *Waste Management*, 29(9) (2009) 2596-2599.

[30] Zhao Y, Christensen T H, Lu W, Wu H, & Wang H, Environmental impact assessment of solid waste management in Beijing City, China, *Waste Management*, 31(4) (2011) 793- 799.

[31] Das S, Lee S, Kumar P, Kim K, Lee S & Bhattacharya S, Solid waste management: Scope and the challenge of sustainability, *Journal of Cleaner Production*, 228 (2019).

[32] Dauvergne P, Lister J, Big brand sustainability: governance prospects and environmental limits, *Global Environmental Change*, 22(2012) 36–45.