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Solid waste management in India

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Abstract
Solid Waste Management is a complex task which requires appropriate organizational capacity and cooperation between numerous stakeholders in the private and public sectors. Although it is essential to public health and environmental protection, solid waste management in most cities of developing countries is highly unsatisfactory. If it is not handled carefully the problem of Solid Waste will multiply and will become a disaster for the world. To resolve this issue, cities and their citizens should join together to create sustainable lifestyles and an ecological civilization in which people and environment coexist in harmony. A Literature review on the subject of Solid waste Management (SWM) is yet in the formative stage as a well classified and large quantum of information is not at hand. This paper summary the literature and inferences gathered so far pertained to the topic. The main focus of this research paper is on Financial Aspect of Solid Waste Management (SWM). Areas such as challenges facing SWM, sustainable SWM, Integrated approach to SWM, Financing options, centralized – decentralized systems of SWM, Environmental Audit of SWM system, Importance of Public-Private Partnerships in SWM, Financial performance analysis of SWM through Cost-Benefit Analysis are covered in this paper.

Keywords: solid waste management, public-private partnership, environmental audit, cost revenue analysis

Introduction
India is the second largest nation in the world, with a population of 1.21 billion, accounting for nearly 18% of world's human population, but it does not have enough resources or adequate systems in place to treat its solid wastes. Its urban population grew at a rate of 31.8% during the last decade to 377 million, which is greater than the entire population of US, the third largest country in the world according to population. India is facing a sharp contrast between its increasing urban population and available services and resources. Solid waste management (SWM) is one such service where India has an enormous gap to fill. Proper municipal solid waste (MSW) disposal systems to address the burgeoning amount of wastes are absent. The current SWM services are inefficient, incur heavy expenditure and are so low as to be a potential threat to the public health and environmental quality. Improper solid waste management deteriorates public health, causes environmental pollution, accelerates natural resources degradation, causes climate change and greatly impacts the quality of life of citizens. Solid Waste Management is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetic, engineering and other environmental considerations. In its scope, solid waste management includes planning, administrative, financial, engineering and legal functions. Solutions might include complex inter-disciplinary relations among fields such as public health, city and regional planning, political science, geography, sociology, economics, communication and conservation, demography, engineering and material sciences. Solid waste management practices can differ for residential and industrial producers, for urban and rural areas, and for developed and developing nations. The administration of non-hazardous waste in metropolitan areas is the job of local government authorities. On the other hand, the management of hazardous waste materials is typically the job of the generator, subject to local, national and even international authorities.

Waste is defined as any material that is not useful and does not represent any economic value to its owner, the owner being the waste generator. Depending on the physical state of waste, wastes are categorized into solid, liquid and gaseous. Solid Wastes are categorized into municipal wastes, hazardous wastes, medical wastes and radioactive wastes. Managing solid waste generally involves planning, financing, construction and operation of facilities for the collection, transportation, recycling and final disposition of the waste. This study focuses only on the disposal of municipal solid waste (MSW).

Objectives of waste management
The primary goal of solid waste management is reducing and eliminating adverse impacts of waste materials on human health and environment to support economic development and superior quality of life.

Functional elements of the waste management system
There are six functional components of the waste management system as outlined below: Integrated Solid Waste Management (ISWM) ISWM is an increasingly important term in the field of waste management. It refers to the selection and use of appropriate management programs, technologies, and techniques to achieve particular waste

management goals and objectives. Waste generation refers to activities involved in identifying materials which are no longer usable and are either gathered for systematic disposal or thrown away.

- Onsite handling, storage, and processing are the activities at the point of waste generation which facilitate easier collection. For example, waste bins are placed at the sites which generate sufficient waste.
- Waste collection, a crucial phase of waste management, includes activities such as placing waste collection bins, collecting waste from those bins and accumulating trash in the location where the collection vehicles are emptied. Although the collection phase involves transportation, this is typically not the main stage of waste transportation.
- Waste transfer and transport are the activities involved in moving waste from the local waste collection locations to the regional waste disposal site in large waste transport vehicles.
- Waste processing and recovery refer to the facilities, equipment, and techniques employed both to recover reusable or recyclable materials from the waste stream and to improve the effectiveness of other functional elements of waste management.
- Disposal is the final stage of waste management. It involves the activities aimed at the systematic disposal of waste materials in locations such as landfills or waste-to-energy facilities.

Waste Management

- **Recycling**

Reducing and reusing are the most effective ways to prevent generation of wastes. Once the wastes are generated and collected, the best alternative to handle them would be recycling where the materials generally undergo a chemical transformation. Sometimes, reusing can also Happen after collection, in cases where informal traders collect materials of no use from households, reshape or repair them and sell in second-hand markets. Unlike reusing a used material, recycling involves using the waste as raw material to make new products. Recycling thus offsets the use of virgin raw materials. It is known that as much as 95% of a product's environmental impact occurs before it is discarded, most of it during its manufacturing and extraction of virgin raw materials. Thus, recycling is pivotal in reducing the overall life cycle impacts of a material on environment and public health. Recycling however requires a separated stream of waste, whether source separated or separated later on (after collection).

- **Aerobic Composting**

Similar to the recycling of inorganic materials, source separated organic wastes can be composted and the compost obtained can be used as an organic fertilizer on agricultural fields. Organic compost is rich in plant macro nutrients like Nitrogen, Phosphorus and Potassium, and other essential micro nutrients. Advantages of using organic manure in agriculture are well established and are a part of public knowledge. United Nations Environment Program (UNEP) defines composting as the biological decomposition of biodegradable solid waste under predominantly aerobic conditions to a state that is sufficiently stable for nuisance-free storage and handling and is satisfactorily matured for safe use in agriculture. Composting can also be defined as human intervention into the natural process of decomposition as noted by Cornell Waste Management Institute. The biological decomposition accomplished by microbes during the process involves oxidation of carbon present in the organic waste. Energy released during oxidation is the cause for rise in temperatures in windrows during composting. Due to this energy loss, aerobic composting falls below anaerobic composting on the hierarchy of waste management. Anaerobic composting recovers energy and compost. Life cycle impacts of extracting virgin raw materials and manufacturing make material recovery options like recycling and composting the most environment friendly methods to handle waste.

- **Energy Recovery**

Energy requirements of a community can be satiated to some extent by energy recovery from wastes as a better alternative to land filling. Energy recovery is a method of recovering the chemical energy in MSW. Chemical energy stored in wastes is a fraction of input energy expended in making those materials. Due to the difference in resources (materials/energy) that can be recovered, energy recovery falls below material recovery on the hierarchy of waste management.

- **Anaerobic Digestion**

The USEPA defines Anaerobic Digestion (AD) as a process where microorganisms break down organic materials, such as food scraps, manure and sewage sludge, in the absence of oxygen. In the context of SWM, anaerobic digestion (also called Anaerobic Composting or Biomethanation) is a method to treat source separated organic waste to recover energy in the form of biogas, and compost in the form of a liquid residual. Biogas consists of methane and carbon dioxide and can be used as fuel or, by using a generator it can be converted to electricity on-site. The liquid slurry can be used as organic fertilizer. The ability to recover energy and compost from organics puts AD above aerobic composting on the hierarchy of waste management.

- **Waste-to-energy combustion**

Waste-to-Energy combustion (WTE) is defined as a process of controlled combustion, using an enclosed device to thermally breakdown combustible solid waste to an ash residue that contains little or no combustible material and that produces, electricity, steam or other energy as a result. Even though both WTE combustion and RDF combust MSW, the objective of WTE combustion is treating MSW to reduce its volume. Generating energy and electricity only adds value to this process. As discussed earlier combusting the organic fraction of MSW (a bio-fuel) and releasing carbon dioxide as the end product is a net zero emissions process. Due to the dominance of organic waste in MSW, MSW is considered as a bio-fuel which can be replenished by agriculture. Also, bio-fuels are renewable. In India, urban MSW contains as much as 60% organic fraction and 10% paper. Therefore, potentially, 70% of energy from WTE plants is renewable energy. Therefore, WTE is recognized as a renewable energy technology by the Government of India (GOI). Australia, Denmark, Japan, Netherlands and the US also recognize WTE as a renewable energy technology.

- **Sanitary Landfilling**

United Nations Environmental Program (UNEP) defines sanitary landfilling as the controlled disposal of wastes on land in such a way that contact between waste and the environment is significantly reduced and wastes are concentrated in a well defined area. Sanitary landfills (SLFs) are built to isolate wastes from the environment and render them innocuous through the biological, chemical and physical processes of nature. UNEP also recognizes three basic conditions to be fulfilled to be designated as an SLF:

a. Compaction of the wastes,
b. Daily covering of wastes (with soil or other material) and
c. Control and prevention of negative impacts on public health and environment.

- **Unsanitary landfilling and open dumping**

There is no specific definition for unsanitary land filling. However, it is generally characterized by open dumping of wastes, lack of monitoring of the site, stray animals and birds feeding on the wastes, absence of leachate or methane collection systems and wastes exposed to natural elements. The direct implications of land filling include burying materials which were extracted by energy and infrastructure intensive and in most cases environmentally harmful methods and in turn depleting earth's natural resources. From an energy recovery perspective, landfilling is equivalent to burying barrels of oil. Apart from these moral implications, land filling causes extensive public health and environmental damage. Landfills create unsanitary conditions in the surroundings, attract pests and directly impact human health. Unsanitary landfills also contaminate ground and surface water resources when the leachate produced percolates to the water table or are washed as runoff during rains. Unmonitored landfills catch fires due to methane generation and heat and result in uncontrolled combustion of wastes, releasing harmful gases like carbon monoxide, hydrocarbons and particulate matter into low level atmosphere. In addition to these harmful impacts, unsanitary landfills contribute to Climate Change by releasing methane, a greenhouse gas (GHG) with 21 times more global warming potential than carbon dioxide (in the first year of release, methane is 71 times more potent than carbon dioxide as a GHG).

- **Landfill mining projects**

Landfill mining in India was observed in cities with closed or overflowing landfills. The author visited the closed landfill in Automaker, Hyderabad, which was being mined for compost by excavating and sieving the land filled material. The compost is sold to organic fertilizer companies to be used in agriculture as a supplement to chemical fertilizer according to the Integrated Plant Nutrient Management policy. This process involves loosening, spraying a bicultural and regularly turning the waste beds. It is then followed by sieving and packing.

By 2007, landfill mining was carried out seven times in five different cities, namely Nashik (in 2003), Madurai, Mumbai (in 2004), Hyderabad (in 2004, 2007) and Pune (in 2006, 2007). These seven projects together cleared more than 60 hectares of landfill area, emptying more than 5 million cubic meters of waste. This corresponds to about 3 million tons of MSW considering a bulk density of 0.5 tons/m3.

- **Bioremediation**

Bioremediation with respect to MSW landfills can be defined as a "cleanup" technology employing biological options, generally bacteria to stabilize land filled organic wastes through aerobic decomposition. The utility in such stabilization is

a. Avoidance of anaerobic digestion of organics and resultant methane emissions
b. Avoidance of leaching and resultant water pollution
c. Value addition to land filled MSW by making it easier to mine them (for landfill mining).

Bioremediation of landfills can also be used to help landfill mining. In this process which is very similar to windrow composting, bacterial slurry is sprayed on mixed waste and the heaps are turned regularly to produce compost which can then be mined. MSW over a hectare of land in Gorai dumpsite was stabilized/bio-remediated and the compost formed was mined along with recovery of recyclables. 9 m tall waste beds over this area were cleared in 3 months with low Investment and infrastructure which is affordable by most Class I and Class II cities in India.

Conclusion

Two decades of economic growth since 1990 has changed the composition of Indian wastes. The quantity of MSW generated in India is increasing rapidly due to increasing population and change in lifestyles. Land is scarce and public health and environmental resources are precious. The current SWM crisis in India should be approached holistically; while planning for long term solutions, focus on the solving the present problems should be maintained. The Government of India and local authorities should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. While this is being achieved and recycling is increased, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future. State Governments should take a proactive role in leveraging their power to optimize resources. Improving SWM in India is imperative. Improper SWM presents imminent danger to public health, India's environment and the quality of life of Indians. Materials and energy recovery from wastes is an important aspect of improving SWM in India. It not only adds value to SWM projects and makes them economically feasible but is also more sustainable. Diverting MSW from landfills and especially from unsanitary landfills in India to any extent will contribute to the cause. India should choose those options or a combination of them, which will:

a. Best address the issue of overall solid waste management,
b. Have the least/no impact on public health and environment,
c. Consume minimal resources and
d. Be economically feasible.

Recycling, composting and waste-to-energy are integral parts of the solution and they are all required. None of them can solve the India's SWM crisis alone. Policy to include waste-pickers in the private sector must be introduced to utilize their low cost public and environmental service and to provide better working conditions to these marginalized populations.

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