A Review on Sustainable Solid Waste Management for UT: Case study of Chandigarh city.

Vikas Balyani[1], Dr. Sanjay Sharma[2], Dr. Amit Goyal[3]

[1]M.E. Student, [2]Professor, [3]Assistant Professor
[1,2,3]National Institute of Technical Teachers Training & Research, Chandigarh, India

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Abstract - This paper presents a comprehensive literature review on the solid waste management system. A brief overview of various types of solid waste is also presented. The impact of disposal of untreated waste on health and environment is also highlighted. In present paper, the state of art on solid waste was thoroughly reviewed in the context of sustainable solution for cities. Based on the observations, conclusion is provided at the end of section. The objective of present study is to formulate a developmental plan for sustainable solid waste management in a plain ecosystem for Chandigarh. Solid waste studied in this present work comprises of both organic and inorganic waste. Different disposal techniques were evaluated and main approach in this study is to identify the most efficient and sustainable solution for the disposal of solid waste. Waste management services involve the activities and actions required to manage waste from collection to its final disposal. The desirable low moisture content, high calorific value of the residual matter obtained from treatment plant at NITTTR campus may encourage adopting similar de-centralized small unit for all sectors of Chandigarh city. The current method of accumulating the waste from entire city at a single location and then adopting unified treatment is not a viable option. Cost analysis was also done to evaluate the economical and affordable conveyance system for collecting and transporting the waste.

KeyWords: Municipal Solid Waste, Sustainable, Municipal Corporation, Characterization of Municipal solid waste, Refused Derived Fuel, Calorific value and Moisture content.

1. Introduction

Solid waste is broadly comprised of non-hazardous domestic, commercial and industrial refuse including household organic waste, hospital and institutional garbage, street sweepings, and construction wastes (Zerboc 2003). Domestic solid waste includes all solid wastes generated in the community and generally includes food scraps, containers and packaging, discarded durable and non-durable goods, yard trimmings, miscellaneous inorganic debris, including household hazardous wastes (for instance insecticides, pesticides, batteries, left over paints etc.) and often, construction and demolition debris.

1.1 Classification of Solid Waste

A Report prepared by World Bank (1999) lists eight major classifications of solid waste(SW) generators:

1. Residential: Includes waste generated in household units, such as food and fruit peels, rubbish, ashes etc.
2. Industrial: Has two components ;Hazardous, which is toxic; corrosive; flammable; a strong sensitizer or irritant and may pose a substantial present or potential danger to human health or the environment when improperly processed, stored, transported, or disposed of or otherwise managed. Non-hazardous which includes inert and essentially insoluble industrial solid waste, usually including, but not limited to, materials such as rock, brick, glass, dirt, and certain plastics and rubber, etc., that are not readily decomposable
3. Commercial: Waste produced by wholesale, retail or service establishments, such as restaurants, stores, markets, theaters, hotels and warehouses.
4. Institutional: Waste that originates in schools, hospitals, research institutions and public buildings.
5. Construction and demolition: Waste building material and rubble resulting from construction, remodeling, repair, and demolition operations on houses, commercial buildings, pavements and other structures
6. Municipal services: Sludge from a sewage treatment plant which has been digested and dewatered and does not require liquid handling equipment etc.
7. Process: Treatment plant wastes principally composed of residual sludge and
8. Agricultural: Spoiled food wastes, agricultural wastes, rubbish, hazardous wastes.

1.2 Problem Description

In a developed country framework, the waste generated from different sectors are generally treated separately while, in developing countries separate treatment of wastes generated from different sectors is usually not undertaken. Improper handling and disposal of solid waste has multi-dimensional impact on human and environmental wellbeing. Improper dumping can lead to:

- Pollution of air, soil, and water,
- contamination of surface and ground water supplies,
- clogging of drains,
- floods in the plains and
- landslides in the hilly areas during rainy seasons.

2. Literature Review

Koppen and Geiger (1918-28) [1] According to his study widely-used vegetation-based climate classification system, the Koppen climate classification system, was created by Wladimir Koppen, a German botanist, and climatologist. The classification system attempts to derive a formula to categorize vegetation zones or biomes across the globe, in accordance with their climatic boundaries. In 1900, the climatic classification was a novel concept. In 1918, Koppen revised his classification system and republished, and continued revising the system until his death in 1940.Introduced as a map in 1928, the Koppen climate classification system was co-authored by Koppen's student Rudolph Geiger. Various geographers have modified and utilized this classification since its first publication by Koppen and Geiger.Csa = Hot-summer Mediterranean climate; coldest month averaging above 0 °C (32 °F) (or −3 °C (27 °F)), at least one month's average temperature above 22 °C (71.6 °F), and at least four months averaging above 10 °C (50 °F). At least three times as much precipitation in the wettest month of winter as in the driest month of summer, and driest month of summer receives less than 30 mm (1.2 in).

Venkateshwaran (1994) [2] According to her study increasing population has caused severe pressure on basic infrastructure and amenities, creating large areas unserved by public services. The municipal authorities are unable to deliver the various sectoral services for want of funds, manpower, technology or efficiency in systems. The labour market, whether it be the formal or informal sector of employment, similarly finds itself increasingly pressurised by the consistent inflow of migrants into urban centres. While industrialisation has created jobs.the increase in employment opportunities has tailed to strike a balance with the additions to the labour force, and even the informal sector is often unable to engage substantial sections of the urban population in gainful employment. Basic services and employment opportunities then emerge as the most prominent and immediate needs of most urban centres today.

Schubeler (1996) [3] He concluded that Management is a cyclical, goal-oriented process .MSWM includes all phases of waste collection, recycling, treatment and disposal. A first goal of MSWM is to protect the health of the entire urban population. The scope of MSWM encompasses planning and management, waste generation and waste handling processes. Residential households want effective and dependable waste collection service at an affordable prices. NGOs may help to increase the community capacity to manage waste collection. National governments are responsible for the MSWM institutional and legal framework. National governments should provide assistance with cross-jurisdictional problems.

Hoornweg et al. (1999) [4] they stated that composting is all too often implemented for the wrong reasons. It will not make large profits, nor will it solve all solid waste management problems. Incentives, such as the availability of government subsidies and soft loans, are frequently used to set up composting projects which cannot be sustained on a long-term basis. Composting should be considered as part of an integrated solid waste management strategy with appropriate processing technologies selected based on market opportunities, economic feasibility, and social acceptance. Cost effective and sustainable composting is possible within the context of an integrated solid waste management strategy. Participation and cooperation from many stakeholders is required, including national governments, municipalities, local communities, waste generators, and the private sector.

Reyer Gerlagh et al. (1999) [5] According to their study both solid and liquid, are being generated as a result of the rapid rate of urbanization. This in turn presents greater difficulties for disposal. The problem is more acute in developing countries, such as India, where the pace of economic growth as well as urbanization is faster.One variable influencing urban SWM is the source of waste and its composition. It is typical that a large resource pool of organic waste is left unused. Although composting as a method of waste recovery does exist in the city, the percentage of waste composted is low when compared to the total compostable waste generated. The main reason for this is the fact that a large percentage of the organic and biodegradable waste is un-segregated and hence unsuitable for composting. Another reason is that while recyclables have an extensive trading network, in the market for organic waste is limited. Similarly, while there is a market for recycled products, the market for compost as a fertilizer is still relatively undeveloped.

Joardar (2000) [6] Besides, the manner in which waste is disposed of especially in the developing world may only suit participation of the public in order to reverse the effects of poor solid waste disposal. He found out that "the most widely practiced municipal disposal method has been uncontrolled dumping, concentrated in low-lying fringe locations and leading to leacheate percolation and pollution runoff and contamination of soil, ground water, canals, and river ways". Uncontrolled dumping when practiced indiscriminately by the public, it imposes far-reaching effects as Sauro points out. However, in itself, dumping is not a sustainable way of management of waste, it would actually be a qualified destructive method, yet it can be controlled and the effects reversed if the public were involved in the waste management and disposal structure.

Mcmichael (2002) [7] According to him the proportion of the global burden of disease associated with environmental pollution hazards ranges from 23 percent (WHO-1997) to 30 percent (Smith, Corvalan, and Kjellstrom 1999). These estimates include infectious diseases related to drinking water, sanitation, and food hygiene; respiratory diseases related to severe indoor air pollution from biomass burning; and vector borne diseases with a major environmental component, such as malaria. These three types of diseases each contribute approximately 6 percent to the updated estimate of the global burden of disease (WHO 2002).As the World Health Organization (WHO) points out, outdoor air pollution contributes as much as 0.6 to 1.4 percent of the burden of disease in developing regions, and other pollution, such as lead in water, air, and soil, may contribute 0.9 percent (WHO 2002). These numbers may look small, but the contribution from most risk factors other than the "top 10" is within the 0.5 to 1.0 percent range

Thorneloe et al. (2002) [8] According to their study America's cities are avoiding the annual release of 52 MMTCE of GHG emissions each year through the use of modern MSW management practices. The total quantity of GHG emissions from MSW management was reduced by more than a factor of 6 (from 60 to 8 MMTCE) from what it otherwise would have been, despite an almost doubling in the rate of MSW generation. This study illustrates that there has been a positive impact on GHG emissions as a result of technology advancements in managing MSW and more integrated management strategies. Although there has been a 60% increase in MSW since 1974, more than 52 MMTCE of GHG emissions per year are being avoided based on actions taken in U.S. communities. There are additional opportunities for decreases in GHG emissions as well as improvement in other environmental co-benefits through improved materials and energy recovery from MSW management. From this study, it can be concluded that the greatest reductions in GHGemissions during the past 25 years have come from technology advancements to recover energy and recycle materials.

Zurburg Christian (2003) [9] He concluded that term municipal solid waste, refers to solid wastes from houses, streets and public places, shops, offices, and hospitals, which are very often the responsibility of municipal or other governmental authorities. Solid waste from industrial processes are generally not considered" municipal" however they need to be taken into account when dealing with solid waste as they often end up in the municipal solid waste stream.In Asian low- and middle-income countries, municipal managers still face many common solid waste management problems. Although in some cities, successful innovative ideas and approaches have been implemented on different levels of the solid waste management system(from household storage to disposal), the know-how and experience is seldom communicated and transferred to others with similar responsibilities.

Chakrabarti (2003) [10] According to her study the available spaces for land filling are getting scarce and land prices are increasing. Second, there has been growing awareness about the environmental and health costs that poorly managed solid wastes can impose. Consequently a large body of literature has emerged which have viewed solid waste problems as "public bad" and accordingly prescribed various market-based instruments that would correct this externality. Deposit- Refund system is suggested to be the optimal policy in most of the theoretical literature. Currently, solid waste management system in developing countries has not largely incorporated market-based instruments.

Hazra, T. and Goel, S. (2009) [11] The rate of solid waste generated tends to increase with the increase in population. Despite existence of various efforts on solid waste collection, still the quantity of solid waste collected is small compared to the solid waste generated. The situation is even worse in unplanned settlements of developing countries, where, ineffective solid waste collection is contributed to by haphazard solid waste disposal and hence environmental pollution. Therefore, having an effective and efficient solid waste management system is a major challenge in cities of developing countries, and thus more consulted efforts are needed. Different groups engaged in solid waste collection are deterred by many challenges. The challenges include: lack of cooperation among the existing solid waste collection organs, inaccessibility in some places, low public participation, financial constraints and unwillingness of local community to pay for solid waste collection fees. The paper recommends four options on how solid waste management, particularly collection in KekoMachungwa can be enhanced. 1) Alliance among the existing organ, 2) placing dust-bins in different points within the settlement, 3) linking the fees of solid waste collection to other public services and 4) education and awareness creation campaigns accompanied by community stakeholder consultations.

Gupta and Gupta (2015) [12] propose that by 2050 half of India's population shall be living in urban area further increasing the amount of solid waste. The authors have done case studies in the city of Chandigarh and has put light on how the solid waste has been treated in different ways in This City. The city produces 135050 metric tone solid waste annually. The primary collection process is carried out at sahajsafaikendras (SSK). From SSK garbage is transported to processing plants and rejected waste is send to the landfills. Besides having good collection and transportation of solid waste in chandigarh the city faces certain challenges. Segregation of solid waste, shortage of working staff, public private partnership are some of the problems being faced in the city in the way of waste disposal.

Rishi et al. (2017) [13] has done chemical characterization of solid waste for various groups of society of Chandīgarh. They have also suggested alternative methods of waste disposal. They concluded that 50% of the waste constituted was the organic waste and 29 % was the inert fraction of socio-economic group. The inert and MSW must not be mixed together so that the processing of biodegradable waste is not hindered. The authors have suggested that RDF could not be a single solution for waste management. Additional techniques such as composting, vermicomposting, bio methanation plant can reduce the burden on MSW system in city like Chandigarh.

Rishi Rana et al. (2017) [14] stated that despite having a well planned SWM system Chandigarh municipality was facing certain challenges. Littering after waste collection, poor condition of bins for collection, distribution of labor and resources, poor working conditions, worn out collection vehicles, segregation of wastes, disposal methods were various problems found by the authors. Public private partnership has been an important factor in successful management of solid waste in Chandīgarh. As compared to Surat Chandigarh lags behind in utilizing the idea of 3R's. Landfill site have no lining to control leachate percolation in ground water. However, plans have been proposed to make a new landfill site free from leachate percolation problem. In addition to this, to treat organic waste of grain market and hotels municipal corporation Chandīgarh will set up a plant where the organic waste will be treated to produce the methane gas. Methane produce can be further used for electricity generation.

Rajiv Ganguly et al. (2017) [15] done a case study on Physical and chemical characteristics of municipal solid waste collected from tricity region of Northernpart of India. For controlling large volumes of solid waste generated in urban areas in India integrated solid waste management system is an effective technique. The rise of integrated solid waste management system depends upon the quantity and its type generated from different sources located in tricity. In this context, characterization studies are often performed on urban solid waste generated to enable suitable decision making for proper management of solid waste generated. The paper presents the characterization ofurban solid wastes generated from the Tricity region of Chandigarh, Mohali and Panchkula in India. The presentstudy characterizes the physical and chemical properties of the Municipal Solid Waste (MSW) generated in all the three study locations for different socio-economic groups. In general, the MSW generation from the Tricity of Chandigarh, Mohali and Panchkula account for approximately 680 tons per day (TPD) of solid waste (380 TPD inChandigarh, 150 TPD in Mohali and 150 TPD in Panchkula). The characterization of the three cities indicates thatMSW generated from all the three cities have high proportions of biodegradables [52% Chandigarh (CHD),46.7% Mohali (MOH) and 42.6% Panchkula (PKL)] with inert fraction as (27% in CHD, 28.6% in MOH and 28.46% in PKL). The calorific value of the MSW generated varies from 1929 kcal/Kg for CHD, 1801 kcal/Kg for MOH and 1542 kcal/Kg for PKL with average moisture content of about 50% in CHD, 46% in MOH and 40% in PKL. Chemical characterization results of MSW reveal variation in elemental carbon with carbon fraction reported being 34.18% in CHD, 33.8% in MOH and 31.9% in PKL city. In the context of the characterization study, the paper also proposes suitable alternatives to the existing MSW management practices including composting, vermicomposting, setting up of a formal recycling unit and installation of bio-methanation plant along with the existing refuse derived fuel (RDF) plant as a comprehensive process for handling the municipal solid waste generated in the Tricity region.

Praneetha Surapaneniet et al. (2018) [16] stated that segregation of waste at the source level is a challenge right now in India. The author proposes use of smart technologies such as ultrasonic sensor, moisture sensor, integration of GPRS, GRS, motion detect sensors for the smart management of waste. Ultrasonic sensor can help to detect the extent up to which the bin is filled so that it gives warning when the bin is about to fill. The idea behind moisture sensors is that it can help to segregate the waste depending upon the moisture content in it. Likewise, the technology can aid to manage the waste in a smarter way.

Nikhat Parvez et al. (2019) [17] proposed that mini autonomous cities can become a model in managing the solid waste. The authors have carried out case study at IIT Roorkee. They concluded that segregating the waste at source level is a significant step in reducing the effort of waste management. This can be achieved by educating the cleaning staff, users and other people at campus. They suggested the accurate design of concrete bin separately for biodegradable and non-biodegradable waste. The highest amount of waste generated at campus is the organic waste. Hence a bio decomposer can essentially aid to decompose the organic waste well and convert into manure.

3. Conclusions

After study various research papers published by different authors following conclusions can be drawn:

1. Waste management services involve the activities and actions required to manage waste from collection to its final disposal. From the household level coverage of solid waste management services in we can say that system does not fulfill the Service Level Benchmark (SLB) of Central Public Health and Environmental Engineering Organisation (CPHEEO).
2. Systematic sorting of waste at the different stages right from the source to the disposal sites was lacking. Incineration has not shown success due to the diverse composition of the waste since it is not sorted.
3. Dumping is not a sustainable way of management of solid waste as due to increase in population in last few decades amount of solid waste also increasing day by day. If dumping will go on in same manner then after few years land for dumping will not

available, so it's important to find out alternate solution instead of dumping.

4. Characterization of waste is an important aspect in disposal of waste and hence it should be given certain consideration while doing solid waste management.
5. Problem of leachate is given least importance. Proper lining of landfill sites is of cardinal importance in order to protect underground water from getting contaminated due to the solid waste specially the biomedical waste.

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