Assessment of Technological Options for Solid Waste Treatment in Kerala

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Abstract- The developing stage of any country is crucial for planning its resources. The sustainable development is the key factor governing the present scenario of social, economic, political, technological, and environmental challenges faced by the world. The Kerala state being enriched by natural resources and good environmental conditions is also going through the phase of urban development. The resulting trends are the increased consumerism which constituted the solid waste management problems along with severe energy crisis in recent times. The proper management of solid waste is the critical challenge faced by the state today. Both these challenges should be resolved in a win-win manner by adopting suitable technological solutions. The present study is an overview of the existing solid waste treatment systems in the state, the major challenges faced and the feasible opportunities for sustainable management of municipal solid waste.

Index Terms- Sustainable development, Biodrying, landfilling, Moisture content, refuse derived fuel

I. INTRODUCTION

The developing Kerala is becoming a heap of solid waste and the social issues related to improper management of solid waste is increasing at an alarming rate. This point out the immediate attention required for developing suitable solid waste management technologies for the state. The sustainability is the main criteria for waste management systems. The detailed studies on existing treatment facilities in Kerala revealed that the anaerobic digestion process is prone to failure after some period of operation in majority of the plants and also the composting process has not succeeded in finding the market for the end product. The incineration of the humid waste is also creating air pollutant leaching in spite of sophisticated control measures, in addition to high economics. The landfilling of waste is not at all the good choice for the monsoon dominating climatic conditions of the state. Also it is a fact that no engineered landfills exist in the state, instead only dumping yards exist which increases the adverse effects. All these indicate the fact that most of the existing technologies for municipal solid waste treatment in the state are unsuccessful. This situation makes it necessary that the development of a sustainable treatment technology is essential to reduce the impacts of municipal solid waste accumulation.

The municipal solid waste of Kerala is found to be having high average moisture content of about 70 % and low average calorific value of 7300 kJ/Kg [1]. Both these factors making many of the treatment options failures and also it cause some economical issues due to high moisture content. Improvement is required in both these parameters which can show the way to a sustainable option. The technology options of different methods of municipal solid waste treatment, prevailing all over the world is studied in the literature review and an innovative biodrying process is proposed to fulfill the sustainability criteria.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

2. MATERIALS AND METHODS

2.1 Municipal Solid Waste Scenario

2.1.1 Quantification Studies

The studies carried out by the National Environmental Engineering Research Institute (NEERI) in Indian cities have revealed that the quantum of Municipal Solid Waste (MSW) generation varies between 0.21-0.35 Kg/capita/day in large cities [2]. Based on this the waste generation in municipalities of Kerala can be taken as an average of 0.28 Kg/capita/day. The studies conducted by the Urban Development Section of World Bank, considering the relation between Gross National product (GNP) and per capita waste generation is estimated to grow at an exponential rate of 1.41% per annum. Therefore the present average generation of MSW can be considered as 0.343 Kg/capita/day, with total MSW generation of 7056 tonnes/day. The database for MSW generation based on direct sampling for the state obtained from literature review is summarised in Table.1.1[3].

Table.1.1. Municipal Solid Waste Generation Estimated Based on Direct Sampling
(Dr.R.Ajaykumar Varma, 2006)

	MSW Generation sources	Quantum of MSW Generation(tones/day)			
		Kollam	Kochi	Thrissur	Kozhikkode
1	Domestic sources	95	134.7	75.75	100.12
2	Commercial establishments	17	32.99	13.02	28.16
3	Marriage & community halls	1	4.75	2.12	1.56
4	Hotel & Restaurants	19	29.9	14.57	24.07
5	Markets	6	20.39	11.01	12.08
6	Institutions/ schools, offices	7	14.75	5.51	10.62
7	Street sweepings	14	31.3	13.87	19.28
8	Hospitals(Non-infectious)	2	4.22	3.6	6.64
9	Slaughter house	2	5.26	2.25	-
10	Construction & Demolition	7	17.0	13.6	11.0
	Total	170	295.26	154.70	213.53
	Per capita generation (g/day/head)	434	482	476	477

Table.1.2. Waste Generation Scenario in Kerala in 2006

Type of MSW	Kollam		Kochi		Thrissur		Kozhikode	
	Collection point	Dump site	Collection point	Dump site	Collection point	Dump site	Collection point	Dump site
Paper	3.10	4.38	4.87	4.42	2.74	3.36	3.32	5.71
Plastic	2.95	4.39	4.83	4.10	2.26	2.46	2.05	2.36
Metals	0.32	0.51	0.35	1.03	0.25	0.61	0.71	0.38
Glass	0.76	1.06	1.06	2.04	0.47	1.36	1.85	0.68
Rubber & Leather	0.84	1.53	1.50	1.42	1.31	2.17	1.50	0.93
Inerts	0.77	0.00	1.74	1.81	1.06	1.82	1.44	1.85
Ash& fine earth	1.90	2.45	1.68	3.68	6.43	3.47	2.75	5.06
Compostable organics	88.34	84.32	79.78	77.14	82.51	81.85	83.9	79.28
Domestic Hazardous	0.17	0.38	0.28	0.74	0.33	0.62	0.93	0.46
	0.85	0.96	3.90	3.64	2.63	2.26	1.55	3.29

2.1.2 Municipal Solid Waste Characterisation Study

The physical composition of typical MSW at collection point and dumping sites obtained from studies are listed in Table.2.1. The average heavy metal content in MSW approximates about 2.84%, which has the potential to contaminate the composting product of the municipal solid waste. The result showed almost 80% of the MSW of the state is organic matter. Considering the chemical properties of typical MSW from the state it is found that moisture content of MSW for the state is very high approximately about 70% (Table.2.2).

Table.2.1 Physical Composition of MSW at Collection Point and Dumping site (%)

Type of MSW	**Kollam**		**Kochi**		**Thrissur**		**Kozhikode**	
	Collection point	Dump site	Collection point	Dump site	Collection point	Dump site	Collection point	Dump site
Paper	3.10	4.38	4.87	4.42	2.74	3.36	3.32	5.71
Plastic	2.95	4.39	4.83	4.10	2.26	2.46	2.05	2.36
Metals	0.32	0.51	0.35	1.03	0.25	0.61	0.71	0.38
Glass	0.76	1.06	1.06	2.04	0.47	1.36	1.85	0.68
Rubber & Leather	0.84	1.53	1.50	1.42	1.31	2.17	1.50	0.93
Inerts	0.77	0.00	1.74	1.81	1.06	1.82	1.44	1.85
Ash& fine earth	1.90	2.45	1.68	3.68	6.43	3.47	2.75	5.06
Compostable organics	88.34	84.32	79.78	77.14	82.51	81.85	83.9	79.28
Domestic Hazardous	0.17	0.38	0.28	0.74	0.33	0.62	0.93	0.46
	0.85	0.96	3.90	3.64	2.63	2.26	1.55	3.29

2.2. Waste Management Concept

There are a number of concepts about waste management which vary in their usage between countries or regions. The waste hierarchy (Fig.3) refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimisation. Activities at source like prevention, re-use and source reduction are given the most priority in solid waste management practices. The energy recovery from the waste is given the second priority, and finally the waste should reach the safe disposal sites.

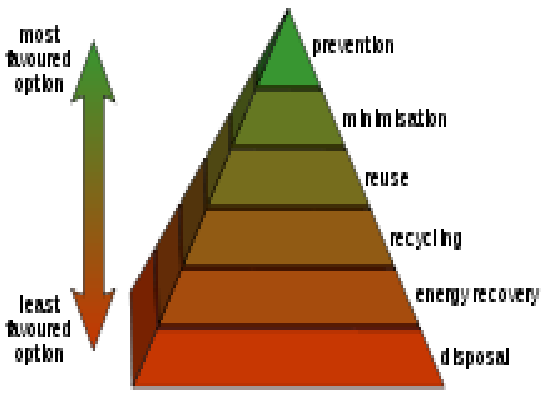

Table.2.2. Chemical Characteristics of MSW at the Dumping Sites of major Cities
(Dr.Ajaykumar varma,2006)

Sl No.	Sampling Location /area	Density (Kg/m^3)	Moisture Content (%)	Calorific Value (K.Cal./Kg)	pH	C (%)	N (%)	C/N	Phosphorous as P_2O_5
1	Kollam	207.06	74.32	1656	7.72	24.97	0.97	25.74	553.5
2	Kochi	267.81	55.29	1759	7.46	26.39	1.25	21.11	129.25
3	Thrissur	335.50	69.52	1744	7.40	28.68	0.93	30.84	1561.17
4	Kozhikkode	327.65	79.54	1816	7.12	32.72	2.43	13.46	1050.17
	Average	**284.51**	**69.67**	**1744**	**7.43**	**28.19**	**1.40**	**22.79**	**823.52**

2. 2.1 Waste Prevention and Minimisation

Prevention is the most desirable waste management option, as it eliminates the need for handling, transporting, recycling and disposal of waste. Also it helps the optimization of environmental resources. Minimisation is any process or activity that avoids, reduces or eliminates waste at its source or results in reuse or recycling. These two management options can be applied at all stages in the life cycle of a product. A case study suggested that "extended producer responsibility" criteria can be used in the selection of resources and the design of products, in the context of 'cradle to grave' evaluation of economic and environmental costs and benefits. The study suggested special tools like life cycle analysis and value chain analysis for the same [4].

Reuse is preferred over recycling if the purpose of use is same, as both energy and matter is saved. But the efficiency of the product may reduce in reuse and also certain products become hazardous in long run, pointing to the versatility of waste prevention and minimisation. The reuse of a building after remodelling is a sustainable option to minimise the construction waste [5].

Recycling involves the treatment or reprocessing of discarded waste to make it adequate for reuse. It conserves resources and energy but sometimes tedious, time consuming and result in net energy loss. General office waste like paper and cardboard are easier to recycle because they contain lots of strong fibers that can be reused to make new sheets, papers etc. The effectiveness of recycled glass as aggregate replacement in concrete improved the durability, impermeability, improved abrasion resistance, hardness, and enhanced flow properties of concrete without using plasticizers. Also the pozzolanic properties of glass aggregates benefit for partial cement replacement and filler [6].

Waste of electrical & electronic equipments (*WEEE*) consists of various reusable commodities and hazardous substances. But recovering both of these in an environment friendly manner is a major challenge. A study on multilateral recycling system in Asia especially proposed a cost-profit analysis model, considering the differentials of economic factors between developed and developing countries at first. Based on this model, a cost-profit analysis of multilateral recycling of four electronic products namely, refrigerator, television, air conditioner and personal computer was performed. The result of analysis showed that high profitability and recycling ratio can be achieved by multilateral recycling system in spite of its extra transportation cost, mainly due to low labour cost in developing countries [7].

Once the matter becomes waste, it should be collected in a systematic manner to transport the same in to a proper treatment or disposal site. The first step in collection includes the storage and separation of waste in different methods. The single bin system (collect all solid waste and liquid waste together), double bin system (collect solid waste and liquid waste separately) or triple bin system (collect biodegradables and non-biodegradables in solid waste separately) can be adopted.

Infectious wastes are biologically active and inherently capable of becoming putrescible. Hence it is essential to implement rapid delivery or temperature controlled transport for the same. Non-halogenated plastic containers should be used for incinerable wastes in place of PVC. Non-halogenated plastics or recycled materials to be purchased for packaging the wastes. Cyto-toxic wastes are to be collected in leak proof containers, clearly labeled as cyto-toxic waste. All Sharps should be collected in puncture proof containers for final disposal [8].

The biomedical waste is sorted based on color, segregated in to containers or bags at the point of generation (in accordance with Schedule II of Biomedical Waste management and handling Rules 1998). Biomedical waste should be transported within the hospital by means of wheeled trolleys, containers or carts that are not used for any other purpose. Off site transportation vehicle should be marked with the name and address of carrier and biohazard symbol should be painted.

2.3 Methodology

The solid waste management techniques along with the challenges and opportunities of each one in a realistic approach should be analysed for suggesting a suitable solution. The literature review analysis method of research had lead to a number of technological options for the solid waste treatment of the Kerala state.

2.3.1 Composting

Composting is a really meritorious process of recycling waste as it can help us to keep our surroundings clean as well as green. It is an effective means of converting non-infectious and non-toxic biodegradable kitchen and other wastes into manure for useful purposes. A study on combination of vegetable waste, cattle manure and saw dust was utilised for high rate composting in a household rotary drum composter. The rotary drum composting process of mixed organic waste yielded suitable compost with moisture content reduction of 61% to 43% and the BOD/COD ratio reduced from 0.94 to 0.23, within composting period of 20 days [9]. The vermicomposting of domestic waste could be an effective technology to convert the negligible resource into some value-added products [10]. But a case study on heavy metal distribution in soil and plant in municipal solid waste compost amended plots revealed that there was an important load/transfer of metal ions from soils to wheat plants [11]. Vilappil composting plant at Thiruvananthapuram is an example for failure of composting technology in the state. The major reasons for these failures are the plants were designed for handling more waste than could be acquired; allocation of funds for plant maintenance was ignored; and local conditions were not considered while importing the technology. Also the chemical analysis by Centre For Earth Sciences Studies (CESS,2011) at Thiruvananthapuram showed that the city waste contains heavy metals like lead, cadmium and arsenic most probably which affected the composting process badly.Thus the composting method of solid waste disposal has to be analysed for detrimental effects, especially if industrial wastes are dumped in to municipal landfills.

2.3.2 Anaerobic Digestion

There are a number of anaerobic reactors, with solid waste feed, working successfully in the country. The anaerobic digestion of organic fraction of municipal solid waste had been conducted in pilot-scale reactor based on high-solid combined anaerobic digestion process yielded efficient bio-gas production [12]. Anaerobic digester (*AD*) found to be successful in reducing the volume of waste going to landfill, decreasing emissions of greenhouse gases and creating organic fertilizer, all at a profit. But many studies have proven that poor design issues along with elevated investment and operating costs are the limitations. The anaerobic digester plant at Sreekaryiam, Kerala is facing operational troubles due to the increase in nitrogen content to inhibitory levels which could lead to the failure of the digesters [13].

2.3.3 Mechanical Biological Treatment

The mechanical biological treatment (*MBT*) includes the mechanical stage of shredding of waste followed by removal of some recyclable material and the biological stage of composting or digesting the waste, usually done in an enclosed system. The potential advantage of *MBT* is that, it reduces the volume of residual waste and the biodegradability, thus reducing the methane and leachate production from the landfill. Potential hazardous waste contaminants of the waste stream will not reach municipal landfill sites due to the sorting of the waste prior to treatment. (Integrated Pollution Prevention and Control, European Commission – Directorate General Joint Research Centre, 2004).

2.3.4 Incineration

The incineration is the process of treating the waste by the combustion of organic materials. Incinerators may reduce the volume of solid waste, but they do not dispose the toxic substances contained in the waste. They create the largest source of dioxins and emit a wide range of pollutants in their stack gases, ashes and other residues [14]. The special benefit of incineration is destruction and detoxification of particular wastes (e.g. combustible carcinogens, pathologically contaminated materials, toxic organic compounds and biologically active materials), rendering them more suitable for final disposal. However, most of the waste is composed of both combustible organics and non-combustible inorganic matter.

The PVC plastic component of medical waste is a major contribution to dioxin pollution when it is incinerated. So the safest option is to segregate the waste before going for incineration and thus reduce the amount of toxic emissions. The toxic emissions from incinerator plants can be reduced by fitting advanced air pollution control equipment. The cleaned city waste incineration energy used for the desalination purpose in a modelling study showed promising and can be studied on a pilot project [15].

2.3.5 Plasma Arc Treatment

A case study on the assessment of electronic waste treatment using the air plasma system in a batch operation showed that it is able to convert the electronic waste into combustible gas and inert solid residues. High mass loss rate of electronic waste was demonstrated in the experimental study, but the costly electrical energy involved in the process is still the main obstacle of plasma arc treatment technology [16].

2.3.6 LandFilling

Landfill is a land that is built up from deposits of solid refuse in layers covered by soil. The organic waste dumped in a landfill site will decompose with time, but the inorganic constituents will be remaining for long time. Since each landfill has its own constituents and the leachate quality of a particular landfill also changes over time; a flexible design is required to treat the varied influent stream.

The main environmental problem associated with land fill is the pollution of ground water. Rainwater percolating through the solid waste carry large amount of pollutants to the ground water aquifers. Hence the sanitary landfill design should include expensive and carefully constructed impermeable layers which prevent the leachate from contaminating the ground water resources [17]. The United Nations Environmental Programme (UNEP) study showed that leachate recirculation landfills (landfill bioreactors) are superior to the conventional single-pass leaching landfills. A case study showed that soil column had ample capacity to adsorb metal contaminants, making the determination of soil potential in land fill site selection inevitable [18].

Also the methane emissions from landfill to atmosphere increase the global warming with a factor of twenty times more than the same quantity of carbon dioxide (Climate Change Congress, 1995). In order to have a remedy for methane emissions, the ineffective clay capping is replaced by a new technique 'Phytocapping.' The study conducted at Rockhampton's Lakes Creek Landfill in Australia concluded that phytocaps can reduce surface methane emissions 4 to 5 times more than the adjacent un-vegetated site [19].

A Comparative study of municipal solid waste treatment technologies using life cycle assessment method concluded that landfill with energy recovery facilities is environmentally favourable. However, the large land requirement, difficult emission control system and long time span, are the limitations [20]. But it is a fact to be taken with due weightage that, the landfill is the final destiny of any type of waste. Open dumping is the common practice in Kerala instead of landfilling. The central government's Municipal Solid Wastes (Management and Handling) Rules, 2000 prohibit open dumping of unsegregated municipal waste; especially in residential areas. The dumping also violates Environment Protection Act, Kerala Paddy Land and Wetland Conservation Act, Kerala Ground Water Act and Coastal Zone Regulation Act.

III. WRITE DOWN YOUR STUDIES AND FINDINGS

3 RESULTS AND DISCUSSIONS

3.1 The Major challenges and Opportunities –Socio-economical

The rapid urbanization, constant change in consumption pattern and social behavior have increased the generation of municipal solid waste in Kerala beyond the assimilative capacity of our environment, and management capacity of existing waste management system. Hence there is an urgent necessity of improved planning and implementation of comprehensive MSW management system for upgrading the environmental scenario of the state.

The existing waste dumping sites in the state are overloaded beyond capacity and under unsanitary conditions leading to the pollution of waster sources, proliferation of vectors of communicable diseases, foul smell and odours, release of toxic metabolites etc. It is difficult to get new dumping yards and open dumping is prohibited by law. This is particularly true for Kerala with severe constraints of land availability, dense population, environmental fragility and expectation for management of solid waste relies on an overly centralised approach. The increasing quantities of plastics and non-biodegradable packaging materials in the municipal solid waste are making the management options more complicated. Therefore the excessive accumulation of solid wastes in the urban environment poses serious threat to the state.

The unhygienic septic character of municipal solid waste is the visible adverse effect leading to growth of disease spreading vectors and other organisms. The invisible effects of careless dumping of solid waste is the pollution of the ground water and soil of the nearby locality, and sometimes it will be spreading in to wider areas depending on the soil and ground water characteristics of the place. The simply dumping practice of municipal solid waste is not only revealing the technological scarcity but also the limitations of the existing technologies in the state. All these circumstances points out that the municipal solid waste management is a major challenge faced by the state and hence the research and development in this field is the necessity of the time. The present project set the goal to develop a sustainable treatment technology for the municipal solid waste of Kerala.

The economical aspects of various treatment technologies like composting, vermin-composting, anaerobic digestion/ biomethanation, incineration, gasification and pyrolysis and sanitary landfilling are studied. The composting is the most simple and cost effective technology for treating organic fraction of MSW. This method however is not very suitable for waste that is too wet and heavy rains affect the operation of open compost plants. Also the land area requirements for compost plants are very large and the flies nuisance and odour problems are prominent. The waste segregation if not properly carried out will lead to toxicity to the compost which prevents its safe application to agriculture [21]. Vermi-composting is preferred to microbial composting these days in small towns as it requires less mechanization and easy in operation. But the toxic material contamination in MSW will kill the earth worms active in composting.

Biomethanisation or anaerobic digestion is a comparatively well established technology for stabilization of sludge, deodourisation and disinfection. But it is suitable only for organic portion of MSW and it does not degrade complex organic matter and inorganic materials. Such materials found to interfere with anaerobic digestion units causing the failure of the unit itself, and hence result in huge economical burden. So the practical application of this technology is limited for MSW. The incineration of waste is another technology used in developed countries for treating MSW. But the high capital cost along with maintenance cost makes it economically non-viable. Pyrolysis /Gasification for MSW treatment also suffer energy recovery issue for solid waste with high moisture content.

The landfilling is the final disposal method of MSW which is also causing economical barriers due to scarcity of land and long distance transportation requirements, besides the ground water and surface water pollution issues and environmental hazards. The other methods of municipal solid waste management like recycling and reuse can be done only if the MSW is sorted. But the increased moisture content of the waste is affecting the sorting and storage of raw MSW and also result in increased volume of waste.

Literature analysis of solid waste treatment technologies pointed out the fact that the failure of the existing technological options is the cause for increased landfill volumes. The open dumping in the streets of the state also uncover the reality that increased volumes of solid waste beyond the assimilation capacity of the treatment facilities available is the major reason for solid waste handling problems. The decision to implement any particular technology needs to be based on its techno-economic viability, sustainability as well as environmental implications, keeping in view the local conditions and the available physical and financial sources. The search for a solution to this critical challenge leads to the technology “Biodrying” which is adopted in many developed nations as a solution to solid waste treatment menace. This technology is eminent in reducing the moisture in the waste and also the numerous end use possibilities are making it a sustainable option.

3.2 Gap Filling Technology

The biodrying is a relatively new sustainable technology for MSW treatment, which is successfully implemented in many developed countries, which seem to reduce the socio-economic limitations of the existing technology. Biodrying process is an aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. This process is different from composting in that the output of the composting process is stabilized organic matter, but the output of the biodrying process is only partially stabilized, which is useful for energy production from the biodried MSW. The biodrying process is of short duration one and hence the emission factors are also short lasting. The energy balance is also achieved (the calorific value of waste is increased to a sufficient level (from 7500 kJ/Kg to 15000 kJ/Kg) since lower air-flow rates are used.

This technology is meritorious to substantially reduce the amount of the waste going to landfill, and offers an alternative to mass burn incineration besides recovering energy from residual waste by producing a refuse derived fuel (RDF) that can be used instead of fossil fuels [22]. In biodrying process, the moisture content of waste is reduced to about 30 to 45 % and hence sorting and storage issues can be reduced to great extent besides the overloading of landfill can be reduced. The output from biodrying process can recover heat if used in incinerators. Also the volume of waste is reduced up to 45% [23]. Therefore biodrying process is expected to minimize the negative impacts of all the existing technologies in the state and hence research and development in this innovative technology is the need of the time.

4 CONCLUSION

The present study of solid waste treatment technologies in Kerala has revealed the critical issues related to solid waste management widely, with a special mention to the challenges faced by the state. This is the most solution seeking problem of the state today, since social, economical as well as the health environment is seriously affected by the improper solid waste treatment technologies in the state. Instead of repeating the failed technologies it is better to develop an innovative system which will be suited to the diversified and changing characteristics of municipal solid waste. The end use of the output from the biodrying process is making it versatile in terms of sustainability and hence it is found to be aspiring since the waste to energy concept should become a reality to meet the fossil fuel scarcity in the very near future.

5 ACKNOWLEDGMENT

The authors express our sincere thanks to Higher Education Forum, Asia-Pacific Education & Research Association for giving a chance to present the part of this research paper “Solid Waste Treatment Technologies- Challenges and Opportunities of Kerala” at an Asian Conference of Civil, Material and Environmental Science (ACCMES 2013) held at Japan, Tokyo on March 15-17th 2013.

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