TECHNOLOGICAL AND SYSTEMIC CHALLENGES IN MUNICIPAL SOLID WASTE TREATMENT AND POLICY OPTIONS FOR SUSTAINABLE DEVELOPMENT IN THE SECTOR

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Abstract

A large number of MSW treatment plants have been set up in the last two decades and more so in the recent past during the JNNURM in the country. However, irrespective of the technology of treatment the level of mortality among such plants is found to be very high. A rigorous case study from across the country brings out a wide range of systemic risk factors affecting long-term sustainability of such plants. Besides the external upstream and downstream issues, the analysis identifies inherent technological challenges affecting performance of the plants. These challenges pertain to, among others, feedstock quality and delivery system; unavoidable and high wear and tear of the plant and equipment entailing high replacements; poor odour and air pollution control measures inviting host community resistance; high sensitivity of biological processes; low energy recovery potential; poor quality and yield of compost/ biogas; and low to very low overall system efficiencies. Ultimate analysis establishes applicability of the Second Law of Thermodynamics and ascertains that a system characterised by high to very high entropy (disorder) cannot sustain a treatment plant as a financially stand alone facility. There is a need to objectively reappraise the current policy and approaches towards these plants. Instead of viewing them as 'waste to wealth' enterprise, they need to be looked as essential municipal infrastructure which are required to minimise municipal liability towards environment and public health. Instead of offering tipping fee corresponding to a small fraction comprising 'rejects', there is a need to go beyond and consider transparent provision of adequate 'gate fee' corresponding to 'all accepts'. There is also a need to consider sanitary landfill as an integral part of the overall SWM system which represents a robust, elastic and forgiving backstopping facility.

INTRODUCTION

As per the Census 2011 the total urban population of the country is 377 million and there are 6166 urban agglomerations and statutory/census towns. Total municipal solid waste generated in these UAs/towns across the country is estimated to be in the range of 113,000 to 151,000 MT/d. With increasing urbanisation and economic growth, average per capita waste loads are rising and evidently the problem of municipal solid waste management is attaining increasingly complex dimensions in all municipalities. In the chain of integrated operations, among others, the component of treatment has received greater attention, apparently with the premise of it being the most critical element under the resource recovery paradigm. With this premise a number of municipalities in the country have gone about setting up treatment plants prior to and during JNNURM (including UIDSSMT) and many more are planning to establish in the coming years. The technologies that have been attempted during last 3 decades are windrow composting, 'waste to energy' - either mass burn or RDF (refuse derived fuel), biomethanation, and couple of large scale and several small scale vermicomposting initiatives.

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India's experiments with advanced treatment technologies started in mid-seventies, under a scheme of the Ministry of Agriculture. Under this scheme 13 compost plants - each of 300 MT/d capacity were set up across the country with the objective of generating organic manure out of MSW. However 12 plants had to be closed down within a short period (under 3 years), apparently due to a combination of internal and external factors. The only surviving plant at Bangalore could operate until around 2009-2010 due to favourable institutional arrangements, but had to be shut down and dismantled recently due to environmental considerations. Since then, the list of closed compost plants has been expanding e.g., several under the central scheme for 10 airfield towns launched in 2003; Thiruannanthpuram, Vijaywada, Thane, New Delhi, Devnar/Mumbai, Kolkata, Jagannathpuri, Shimla, Shillong, etc.

Subsequently in 1987 an advanced mass burn technology based plant was set up at Timarpur in Delhi (300 MT/d, 3.75 MW), but that again had to be closed down within a short period of 6-9 months of commissioning. In the late nineties, biomethanation and RDF technologies were piloted under the programme for developing non-conventional energy sources. Under this scheme, the biomethanation plants at Lucknow (300 MT/d, 5MW, 2003) and Chennai (30 MT/d, 260 kW, 2005-06) closed down within one year of commissioning, while the Vijayawada plant (20 MT/d, 150 kW, 2004-07) operated for about 3 years before finally closing down - apparently for want of engine spare parts. Among the RDF plants as well, there are quite a few available references of closed plants in the country viz., Baroda (100 MT/d), Mumbai (80 MT/d), Guntur-Vijaywada (2x200 MT/d, 5 MW, 2003-06), Jaipur (500 MT/d, 2008), etc. These RDF plants experienced several systemic and technological problems and closed down within a period of 1-5 years. Likewise in Mumbai a large-scale (400 MT/d, 1994) plant based on vermin-composting process was developed at Devnar/Mumbai which experienced premature closure within a short period of time. In this context, the case of Vijayawada is most relevant and intriguing as during 2002-06 it established three plants based on different technologies viz., composting, RDF and biomethanation, with a combined capacity of around 520 MT/d. However by 2008-09 all the three plants were dysfunctional, and in absence of the required investment in a sanitary landfill, the city was experiencing systematic open burning of waste at the dump site or indiscriminate disposal on the outskirts as well as along the exit highways.

Apparently because these plants produce value added outputs in the form of either compost, biogas, RDF, or electricity, they are perceived to be like typical industrial enterprises and which are expected to sustain themselves through revenues from sale of the output. However, very often it is observed that irrespective of the operator (either the ULB or under a PPP) such treatment plants close down in short- to medium-term due to a plethora of internal and external systemic factors and perforce do not bring the desired environmental and public health benefits, least of all the financial returns.

The challenges that all MSW treatment plants face are systemic which can be related to, among others, feedstock, technology, technical issues, institutional arrangements, financial returns, and environmental and social concerns, etc. However, there are a set of challenges which are common to all type of MSW treatment plants while there are others which are specific to a technology. This paper attempts to bring out a range of most critical challenges which can manifest in early stage of a typical MSW plant whereby undermining its operational continuity, and therefore builds a case for

(a) adoption of least risky options and (b) provision of a robust ‘gate fee’ as the required incentive for the operator to sustain operations.

THE COMMON CHALLENGES

Irrespective of the technology, a typical MSW treatment plant faces challenges related to project development and feedstock. Secondly, an MSW treatment plant by its very nature is a negative externality and thus involves environmental and social issues. These are briefly discussed in this section.

Lack of stakeholder participation

Fast tracking of project development and positioning it as ‘waste-to-wealth’ initiative prevents participation of local stakeholders in the process and also creates misunderstanding with regard to the liability of the beneficiaries towards its sustained operations. Among others, the municipal workers and the host community are main stakeholders as they perceive to be adversely affected by the project.

The challenge of source segregation and feedstock quality

Above all the technology options, the constraints in source segregation and separation system itself are rather challenging. After 12 years of introduction of the MSW Rules, 2000 it is evident that no municipality across the country can make the claim of achieving segregation of waste at source. Given the diversity of sources of waste and the diversity in socio-economic and educational background (literacy, awareness, concern towards environment/public health) of waste generators from different strata of the society across the country, source segregation is an extremely challenging, if not an impossible task. ULBs do not have the commensurate resources and expertise to provide for sustained awareness creation. Secondly, on their part the city residents do not seem to demonstrate such level of discipline and commitment either on a sustained basis.

Further, on a given day over 300 different type of material could constitute mixed MSW stream and their relative fractions can vary on hourly, daily and seasonal basis. At the level of the treatment plant even the best available configuration of pre-processing machinery is unable to handle such variations in quality and quantity of mixed MSW and is therefore unable to produce a consistent quality of feedstock for processing in downstream units. Presence of abrasives e.g., ash, dust, drain silt, stones, construction debris; and corrosive materials e.g., leachate from rotting organics result in high wear and tear and corrosion of the equipment which forces operators to replace plant and equipment once every 5-6 years as against 10-12 years in a typical manufacturing industry. This is a worldwide feature of all MSW plants which entails high recurrent replacement costs.

Environmental, health and social concerns

Any MSW treatment plant has an unavoidable adverse environmental footprint and the corresponding social impacts. Among others, odour emissions, impairment of aesthetics and contamination of surface and ground water sources are the main issues. More significantly, the health concerns that arise comprise psychosomatic impacts – giddiness, vomiting, loss of appetite;

adverse consequences of flies and insects bites, etc. For the host community as well as those along the long haul routes, these in turn translate into lowering of property rates and very often being ostracised by others. Therefore any project without appropriate environmental and social safeguards stands to encounter significant resistance from the affected communities. As experienced in the case of Thiruannanthpuram, Thane, Vijaywada, Bangalore (KCDC) and several other cities, such resistance can be debilitating and could eventually lead to closure of the facility.

CHALLENGES IN COMPOSTING

Generally it is perceived that the conventional 'low cost' technology of windrow composting is the 'most appropriate' option under Indian conditions. However, this being a low energy input system, it runs profound risk of adverse environmental, health and social impacts due to odour emissions as listed above. Secondly, with mixed municipal waste there are concerns on quality of compost due to presence of toxic heavy metals, antibiotics, pathogens, weed seeds, glass pieces, sharps, needles, etc. Thirdly, the nutrient value of MSW derived compost is very low and its shelf life is found to be less than three months. Fourthly, while the plant produces compost on daily basis, its demand among farmers arises only at the time of sowing which is typically twice or thrice a year.

Thus while on one hand there is low premium on MSW derived compost due to quality concerns, overall sales volumes are also limited due to erratic demand pattern which together limit overall revenue realisation for operators.

CHALLENGES IN VERMI-COMPOSTING

While vermin-compost is a relatively superior product, its production is quite a challenge. First of all it is suitable for only small-scale application and not an appropriate solution for large-scale application e.g., 100-300 MT/d capacity plants. Secondly, the indigenous species of earth worms are not found to be very effective, while the exotic species are found to be costing anywhere between Rs. 500-1000/kg or more. Thirdly, the worms can not be fed raw waste but only pre-digested waste, thus necessitating pre-processing of waste to avoid toxicity. Fourthly, earth worms are very sensitive to temperature (ideally between 20-28°C) and die off due to intrinsic heat build-up in the rotting pile or during summer when a major part of the country experiences temperature above 42°C. Earthworm mortality is also reported during severe winters. In order to prevent heat build-up rotting waste needs to be stacked in shallow 'vermibeds' (and adequately insulated during winters). This together with the pre-processing requirement translates into a very large foot print of the facility. Finally the worms also need to be protected from predators such as centipedes, snakes, rodents, birds, hens, and red ants. Because of these reasons, they require great care. In view of these constraining factors, it is found that sooner or later most well intentioned vermincomposting initiatives come to a close. One large scale initiative for 400 MT/d capacity was attempted at the Deonar disposal site in Mumbai during mid nineties and was abandoned within a very short period of time when the above cited challenges became evident.

CHALLENGES IN WASTE TO ENERGY SYSTEMS

For the 'waste to energy' systems - mainly comprising mass-burn and RDF options, the major constraining factor is low calorific value of the feedstock (800-1500 kCal/kg). Open disposal of

MSW on street corners, scavenging of combustible recyclables, high moisture content (especially during monsoon), high presence of inert – particularly road sweeping and construction debris, etc. are the main concerns and the ULBs have no control to guarantee any better feedstock quality. The waste therefore does not burn on its own in conventional boiler/ grate design but perforce requires supplementary fuel e.g., diesel, rice husk, wood chips, etc. Evidently this translates into high operating costs. While improved technology based boiler/ grate designs adopted in the case of the recent WtE plant in Delhi can now achieve self sustaining combustion with low calorie feedstock (~ 1100 kCal/kg), there are still concerns on relatively high plant wear and tear due to high inert content.

Secondly, unlike the cold climate countries where the waste heat (from cogeneration systems of waste-to-energy plants) is utilised for district heating, there is very little scope for its utilisation in a warm climate country like India. As a result the net energy utilisation efficiency is merely 22-25% and thereby the revenue model remains weak. Thirdly, there are issues related to toxic emissions, capital and operating costs of pollution control systems (either by maximum achievable control technology (MACT), or best available practicable technology, (BAPT)) and the concurrent monitoring mechanisms.

Lastly, in case of an RDF to energy plant (and for that matter in others involving multistage processing), the overall system efficiency can be as low as 12-15% considering the first step of fluff or briquette making with of 50-60% efficiency, and the second step of power generation (sans cogeneration) offering 25% efficiency. With such a low overall efficiency in a production/ manufacturing operation, return on investments merely from sale of electricity may not be attractive and sustainable.

CHALLENGES IN BIOMETHANATION

In the case of biomethanation, process sensitivity to temperature variations and 'low dry solids' systems (~8-10% solids and 90% water) are seldom perceived as risks but they turn out to be profoundly critical. Temperature variation in the reactor beyond ±2ºC from the optimal (~37 ºC or 55 ºC) can disrupt the biological process, however due to cost considerations necessary technical safeguards are seldom adopted. Secondly, low dry solids technology entails addition of large quantity of water which results in large reactors and capex as well as adversely affects its heat balance, especially in winter. Last but not the least, biomethanation process is also very sensitive to feedstock toxicity, and over or under loading, etc. and which are not easy to avoid while dealing with a mixed MSW stream.

Next challenge is with the process product and its usage. Since the biogas so produced is generally corrosive and odorous which together make adverse impacts on the equipment, engine, surrounding structures and the health and well being of the community in the vicinity – the effect of the latter aspect already explained in the context of composting. Next, the biogas engines brought from overseas (until recently were not manufactured indigenously) are found to be expensive both in terms of the capital and repairs and maintenance costs. Apparently the Vijayawada biomethanation plant closed down due to, among others, non-availability of engine spare parts at affordable rates. Finally there are issues related to connectivity with the grid, energy pricing, revenue realisation, etc.

THE COST DIFFERENTIALS

The cost differentials among different MSW treatment technology options are of an order of magnitude. For instance capital expenditures (ball park estimates in 2012) involved in setting up a 300 MT/day plant based on different technologies are as follows:

(a) Conventional windrow compost technology: Rs. 8-10 Crore
(b) Mass burn WtE: Rs. 37-40 Crore
(c) RDF followed by WtE: Rs. 65 Crore
(d) Biomethanation followed by energy gen: Rs. 100 Crore

Notwithstanding the comparative advantages of lower ultimate footprint of the WtE options and restricting organics into the landfills, it should be evident that **for the same quality and quantity of feedstock**, the higher order technologies with their increasing capital investments may not be able to provide commensurately higher level of value addition on the outputs (viz., biogas, RDF or electricity, etc.) and revenue realisation.

THE ULTIMATE CHALLENGE

Finally it all boils down to the fundamental **Second Law of Thermodynamics** and the field of municipal solid waste management represents one of the most classical examples of its applicability. As per this law any system at a state of equilibrium would tend to move from a state of low entropy (disorder) to high entropy. In the case of solid waste, at the point of generation (household, establishment, etc.) itself the waste acquires a fairly high degree of entropy because of inevitable mixing, and which is resulting due to the entropy from lack of discipline, education, awareness, concern and commitment on the part of urban residents. As the feedstock moves down the collection chain its entropy increases at every stage, i.e., at community waste depots, in the transporting vehicles and at the transfer stations before finally arriving at the pre-processing stage of a treatment plant. Given the large quantities and inherent nature of putrefaction of municipal waste, overall entropy of the feedstock (mixed MSW) can only be considered to be rising. Entry of inert fractions such as construction debris, road sweepings, drain sludge and other contraries/ toxics; and indiscipline on the part of the collection and transport workers only provide a compounding effect.

At the treatment plant, entropy in the broadest sense of the term is exhibited in the form of odour and other emissions, leachate discharges, process malfunction, and frequent plant breakdowns due to comparatively higher wear and tear, etc. On the product front it is experienced, for instance in the form of contaminants in compost or corrosive property of biogas, etc. Again in the broadest sense, weak institutional arrangements can also be considered contributing to the systemic entropy.

It's the property of entropy that the values of sub-components of a system do not add up but only multiply, and therefore in the case of a typical municipal solid waste management system it needs to be recognised that its entropy only goes exponentially in one direction and that is upwards. According to the **Second Law of Thermodynamics,** in order to contain entropy of a system, external force/ energy needs to be applied. In this context, limited efforts for segregation at source; and reuse, recovery and recycling by various stakeholders during the process only represent small steps towards reduction of entropy in the system, however in relation to the rapidly rising waste loads these are not significant. Treatment of waste, irrespective of the technology, represents that major stage of external energy input into the system whereby entropy of the feedstock – or let's call its nuisance and hazard value, is attempted to be reduced significantly. Sanitary landfilling of the waste and the process rejects represents the next stage of significant energy input into the system whereby the putrefying, pathological, objectionable and at times hazardous matter is eventually contained into a comparatively smaller volume, thereby safeguarding environment and public health in the short-, medium- and long-terms.

POLICY CONSIDERATIONS FOR SUSTAINABLE INITIATIVES

From the comprehensive analysis presented in preceding sections it is evident that treatment of municipal solid waste – whether mixed or segregated, should be not viewed as 'value addition' to a 'resource', but only as an effort to minimise environmental, public health and safety liability of a municipality. The value added products e.g., compost, RDF, biogas, electricity and other recyclables should only be considered as incidentals. In view of the high mortality rate among solid waste treatment plants of all types experienced across the country during last three decades, it's evident that on life-cycle basis the 'energy input' and therefore the resources or costs to run them turn out to be much higher than the potential revenues from all possible sources. This is applicable in both the cases - whether the plant is run by a ULB or by a private service provider.

In recognition of the overwhelming challenges, uncertainties and financial unviability of a typical MSW treatment plant, progressive municipalities across the world have extended a set of fiscal and financial incentives to the service providers. In absence of such incentives ***(transparent and adequate),*** it is understandable that the initiatives in the country with private sector participation could not be sustained in the past. It is encouraging that SWM projects in India in the recent years are being developed under an integrated format (covering collection, transport, treatment and safe disposal) for 'public private partnerships' with a provision of 'tipping fee' to the service provider. However, tipping fee corresponding only to the 'process rejects' and which again are assumed to be unreasonably low at 20-30% of all incoming waste is not sufficient. Experience shows that service providers are increasingly finding it difficult to sustain operations. As a matter of fact international best practice involves payment of 'gate fee' corresponding to 'all accepts' at the gate of an 'integrated treatment and disposal facility' rather than merely for the rejects destined to the landfill. It is also noteworthy that gate fees in such cases are reported to vary in the range of USD 60-200 per MT of waste received depending on local circumstances, and which eventually ensure operational and financial sustainability of the essential municipal infrastructure.

Treatment of municipal solid waste is only a means to an end. The end objective of an integrated operation is **safeguarding public health,** which is to be achieved through a combination of waste reduction, collection, removal, processing and safe disposal in sanitary landfills. However, due to a variety of reasons e.g., desire to recover part of the operating costs, make the initiative attractive for private sector participation, promotion of particular technology solutions, etc. the component of solid waste treatment alone has in general been projected to be an end in itself under the apparently attractive paradigms of 'waste to energy' and 'waste to wealth'. As evident from numerous failed initiatives these paradigms are not sustainable on stand-alone basis and therefore need to be reappraised objectively in the light of cumulative Indian experience of last three decades as well as the international experience.

Technology choices

Considering a MSW treatment plant to be only a 'rendering plant' for minimising its 'nuisance' or 'objectionable' nature, one of the first criteria for technology selection would be low capital and operating costs. Evidently composting with adequate environmental safeguards (for odour control) would qualify on this basis. In this respect it would be pragmatic for Indian project developers to consider the option of 'aerated static pile' composting technology which represents a slightly improved version of the conventional windrow technology.

Where adequate land is available and where the feedstock does not offer comfort in terms of either fuel value or organic content, the option of 'bioreactor' type sanitary landfill could be considered. A bioreactor can offer a sustainable solution whereby one can harness landfill gas as energy source without making any investment in sensitive and depreciating processing plant and machinery. It is intriguing that despite having large quantities of predominantly organic MSW and large number of open dumps, we do not have a single landfill methane capture system in the country. The Gorai dumpsite capping project comes closest to it, but since it is more of a restoration intervention, there is limited potential for landfill gas capture there.

If the argument of paucity of land and the spiralling land prices in urban areas is too strong, then looking at the growing quantity of waste, spreading open dumps, indiscriminate open burning and intrinsic technical unviability of any of the technology options discussed in this paper, it is time that we start including the **robust option of mass-burn** with or without **supplementary fuel and accompanied by MACT or BAPT for emission control**. In terms of overall system performance, this option offers highest efficiency, has lower foot-print, reduces waste volumes by 95% and can be tailored to minimise toxic emissions. To some stakeholders this might appear radical, but after living for more than a decade with non-compliance of the MSW Rules, 2000 across the country, it is time for us to draw lessons and consider appropriate and robust options under demanding boundary conditions as found in all the metros and other rapidly growing cities. However, it is paramount to reemphasise that this option also needs to be offered commensurate and genuine fiscal and financial incentives, i.e., 'gate fee' for all 'accepts' to be financially sustainable and of interest for serious private sector participation.

Finally ULBs needs to recognise that there is no escaping from a well operated and maintained sanitary landfill (SLF) and they need to make adequate provisions for the required area and resources. An SLF needs to be recognised as a robust, elastic and forgiving bedrock for an effective citywide or regional solid waste management system and that needs to be operated and expanded all the time.

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