Indo-US
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Project Notes

Note No. 38

Bioreactor Landfill - A Sustainable Option for Municipal Solid Waste Treatment and Disposal in India

India's 5,100 ULBs are grappling with the problem of treatment and disposal of municipal solid waste (MSW). To treat and dispose of MSW GoI's MoEF MSW Rules, 2000, make it mandatory for ULBs to set up processing plants, while only permitting non-biodegradable, inert waste to be deposited in landfills. To comply with the MSW Rules, 2000, India's municipalities have experimented with various treatment technologies, including windrow composting, mass burn, refuse derived fuel (RFD), biomethanation, and vermi-composting, all of which have experienced mixed results due to many inherent risks. This Project Note describes an advanced form of landfill, called 'bioreactor', which offers a sustainable option to address many of the risk factors associated with conventional MSW treatment technologies.

BACKGROUND

India has close to 5,100 municipalities where the problem of treatment and safe disposal of municipal solid waste (MSW) has reached critical dimensions. The intensity and extent of the problem in the 35 million plus population cities is evidently severe. It is estimated that the 285 million urban population ($\approx$ 28% of the total population) is generating almost 120,000 MT/d of MSW; the outskirts and slums of most cities and towns are characterised by open dumps. While in the last couple of years a number of municipalities have been able to make significant improvements in collection and transport of waste, their progress on the safe disposal front has been limited. It is estimated that while collection and transport typically account for 90-95% of a ULB's MSW management budget, treatment and disposal get only 2-5%. This skewed resource allocation is attributed to a variety of factors, e.g., lack of appreciation of the potential adverse environmental and health impacts from open dumps, large upfront requirement for finances and land, limited in-house technical and managerial capacity, etc. On the other hand, notwithstanding these limitations, a number of ULBs in their attempts to reduce this 'negative externality' have pursued the paradigm of 'resource recovery' and have set up various technology-based treatment plants, e.g., windrow composting, mass burn, refuse derived fuel (RDF), biomethanation, and vermi-composting. Because these technologies hold out promise of producing a value added product, they are perceived to be potentially profitable. However, experience shows that such initiatives often close down in the short- to medium-term due to a combination of technical, financial, institutional, market, social, and environmental risk factors. Instead of achieving the desired environmental and public health benefits, they leave the ULBs with non-performing assets compelling them to revert to the old practice of open dumping.

MINISTRY OF ENVIRONMENT AND FOREST MUNICIPAL SOLID WASTE (HANDING) RULES, 2000

The MSW Rules, 2000, provide a comprehensive framework for ULBs to address their responsibility of collection, transport, treatment and safe disposal of mixed solid waste. From the point of view of treatment and disposal, which is the focus of this Project Note, the Rules adopt a prescriptive and holistic approach. For instance, composting and biomethanation are prescribed for the organic fraction, while energy recovery and palletisation are recommended for the combustible fraction of the mixed waste. Such an approach is based on the 'reuse, recycle, and recover' paradigm, as well as to minimise land requirement. From the latter point of view, the Rules permit only non-biodegradable, inert waste and other non-recyclable waste, including rejects and residues from the processing plants, for disposal into landfills. As a corollary, the Rules make it mandatory for ULBs to set up a processing plant, notwithstanding any unfavourable local circumstances, which may prevail.[1]

[1]On account of such a condition, the Surat Municipal Corporation (SMC) constructed a well-designed sanitary landfill site without a processing plant (which was perceived to be unviable), but was not permitted to commission the facility. As a result of the standoff between the SMC and the State Pollution Control Board, the landfill site has lain idle for the last five years. It requires emptying of runoff after every monsoon and is experiencing erosion of embankments and general degradation.

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While the Rules prohibit disposal of biodegradable waste into landfills, they prescribe installation of landfill gas collection systems, mainly from an air pollution control point of view. At the same time the Rules also recommend, where feasible, utilisation of gas captured for energy generation. However, in practice the two conditions are incompatible as the former would lead to significantly reduced gas production and would make the latter preposition financially unviable. As a result of such restriction and ambiguity, the Rules do not permit development of alternative landfill systems, which are otherwise designed and operated for maximum production and capture of landfill gas, a potential source of renewable energy.

RESPONSE - CONVENTIONAL SOLUTIONS IN INDIAN CONTEXT

The MSW Rules lay out an implementation schedule over a time frame of three years. As per this schedule, the ULBs were mandated to: (a) improve operations at the existing dump sites by December 31, 2001; (b) identify land for sanitary landfill sites by December 31, 2002; and (c) set up processing and disposal facilities by December 31, 2003. However, barring improved collection and transport in selected cities, not much has been achieved on the above three counts even after seven years of notification of the Rules. Secondly, with a fair degree of emphasis on 'processing of waste', ULBs in general have attempted to develop treatment plants as the end solution. In this regard windrow technology based composting has emerged as the most popular option because of its apparent simplicity and affordable cost. A number of municipalities across the country set out to construct compost plants after the enactment of the Rules. This trend gained momentum with the grants available under the 12th Finance Commission, as well as under the centrally sponsored JNNURM program in 2006. About the same time when the MSW Rules were enacted, other initiatives to pilot new technologies were also being tried, e.g., biomethanation in Lucknow, Chennai and Vijaywada; and RDF (refuse derived fuel) with energy generation in Hyderabad and Vijaywada, etc. In the pre-MSW Rules, 2000, era, several treatment plants were constructed across the country, e.g., compost plants at Thane, Mumbai (4), Gwalior, Bhopal, Bangalore, Shillong, Shimla, Mysore, etc.; mass burn plant at Timarpur (New Delhi); and RDF plants at Mumbai and Baroda, respectively.

One common feature of these initiatives was the lack of an accompanying sanitary landfill site. The focus was on conversion of waste into a value added product and revenue generation therefrom, while the need for safe disposal of rejects and contraries was not immediately perceived. The rejects were typically dumped outside the plant, which in due course attained the shape and size of an open dump. In the event of plant shutdown, or temporary or permanent closure, the ULBs were confronted with the original challenge of locating new dump sites. This practice was a result of not normally allocating sufficient resources and clearly defining the responsibility for safe eventual disposal in the contracts of private operators, which thereby undermined the initial objective of safeguarding the environment and public health.

Another feature of these initiatives was their ULB-specific scale, rather than attempting to take advantage of economies of scale by developing regional facilities. The cost of long distance transport and issues related to inter-ULB cooperation, among others, were perceived to be constraining factors.

Early generation projects were under the ownership of the respective ULBs, while private partnership was the preferred route during the last decade or so. Under the latter arrangement, operators were required to bear both the capex and opex, were to get mixed waste at the gate free of cost, and share a part of the revenue/ profit with the ULBs out of the sale of compost/ electricity/fuel, etc. Under the JNNURM grant scheme, capex is being partially taken care of by the ULBs, while opex is the responsibility of the private operator, who is expected to generate profits from sale of the finished products. Lately, the possibility of getting carbon credits is perceived to be a potential revenue stream, however, so far no facility has been able to avail them.[2]

Experience from Treatment Initiatives

In the Indian context, solid waste treatment is a 'negative externality', which is full of risks at all stages of collection, transport, treatment and disposal. Box 1 presents a snap shot of the Indian experience, wherein it is seen that none of the technology options guarantees long-term success. The risk factors, as summarised in Box 2 and which encompass technical, institutional and financial aspects, are sufficiently severe that invariably most plants, in the absence of adequate fiscal incentives, face an uncertain future. In recognition of this inherent feature the concepts of 'tipping fee' and 'gate fee' have evolved to offset the operating costs and provide a reasonable incentive for the private sector to engage on a sustainable basis.[3]

Evolving Model

With accumulating experience, the need for safe disposal of rejects is now acknowledged. The evolving model typically comprises a treatment plant in conjunction with a sanitary landfill. The benefits of regional facilities are also being increasingly realised and a few facilities in Gujarat, Andhra Pradesh and West Bengal are being planned on these lines. One such project, which the Indo-USAID FIRE (D) project has supported over the last two years, involves five separate ULBs under the umbrella of the Asansol Durgapur Development Authority. The evolving financial model comprises provision of tipping fee corresponding only to the quantity of rejects going to the landfill. However, the operator is still expected to generate profit from running compost plants. India's MSW sector policies, however, require further evolution to recognise that: (a) MSW treatment plants intrinsically operate at 'net costs'; and (b) the entire

[2] The Lucknow plant is the only plant that was able to receive confirmation/accreditation under the CDM mechanism for carbon credits, which unfortunately closed down within six months of commissioning and led to lower credit ratings being accorded to similar project proposals in the sector.

[3] 'Gate fee' is the amount paid on 'accepts', e.g., the entire quantity of solid waste from a ULB delivered at a treatment plant ahead of a landfill. 'Tipping fee', on the other hand, corresponds to only the amount paid on that fraction of the solid waste (rejects from the treatment plant and contraries), which is being disposed of into the landfill. The former recognises the inherent 'net cost' characteristics of a treatment facility and helps augment sustainability of integrated operations.

Box 1: Experience with MSW Treatment Plants in India

The mass burn plant at Timarpur in Delhi was among the first advanced technology options to be tried in India in 1987-88. Apparently, due to low calorific value of feedstock and, therefore, high cost of supplementary fuel, it had to be closed down within six months of commissioning.


Broken screen at a compost plant

Likewise, the 300 MT/d biomethanation plant set up in Lucknow in 2001-03 under public private partnership (PPP) had to be closed down within a year of commissioning apparently due to, among others, poor quality of feedstock and a host of institutional and financial uncertainties. Likewise, the Chennai plant, based on the same technology, also came to a close in 2006-07.

The RDF plants in Vijayawada and Guntur set up under PPP were shut down in mid-2007 after struggling for over four years due to a number of technical, institutional and financial challenges. The Hyderabad plant based on the same technology has also encountered similar challenges, but has managed to continue operations under a fair degree of financial uncertainty. The pilot RDF plant at Mumbai, which served as the basis for the three projects in Andhra Pradesh, was completely dismantled due to weak financial viability and high wear and tear of equipment. For similar reasons, the Baroda plant was also closed down.

Under the category of composting technology, there are various examples of closed plants, e.g., Delhi, Mumbai, Bhopal, Gwalior, Mysore, Thane, Shimla and Vijayawada, etc. A variety of reasons is attributed for their closure, i.e., poor quality of feedstock, poor delivery by ULBs, lack of market/marketing skill, poor financial returns, etc. The Thane plant was completely dismantled under court directions on account of severe odor nuisance. The Shimla plant was unable to sustain microbial growth in windrows due to low average ambient temperature. The Trivendrum plant experienced severe problems, among others, on institutional and social grounds.

Box 2: Range of Risk Factors in MSW Treatment


An excessively overloaded compost plant causing odor nuisance and facing resistance from community

Common to all technology options

Fluctuating characteristics of feedstock, high fraction of contraries, presence of abrasives and corrosives are some of the basic challenges that result in excessive wear and tear and frequent breakdown of equipment.

Uncertain delivery of feedstock of required quality and quantity from ULBs, lack of control of the plant operator on ULB fleet and workers, ULB's expectation of royalty, lack of (sweat) equity for municipal workers and fleet drivers, lack of community participation in project development, weak land use regulations, and uncertainty in getting carbon credits are some of the institutional challenges. On top of these, financial challenges arise due to inadequate fee for full waste loads, high cost of equipment repairs and replacement, additional cost of pollution control, and transport and safe disposal of rejects to non-contiguous landfills.

Composting

Severe odor nuisance potential, poor fertiliser value, presence of contraries and contaminants, large storage requirement due to seasonal off take and deterioration on prolonged storage are some of the basic technical risk factors. Likewise, vermi-composting is equally challenging due to high sensitivity of worms to temperature variations, their inability to digest raw waste, unsuitable indigenous species, high cost of exotic species, and predation by other animals. The plants also typically shut down during monsoon season.

The biggest challenge is marketing and sale of compost. Factors which have compounded the problem in the past comprise lack of incentives on compost vis-à-vis high subsidy on chemical fertilisers, lack of standardisation on quality, lack of demand in the local market, limited marketing skills with ULBs, long distance transport, and finally low sales realisation.

Biomethanation

The micro-biological process is very sensitive to and can be disrupted by fluctuations in ambient temperature and toxicity in feedstock. It is also characterised by fluctuation in biogas quantity and quality, and its highly corrosive nature, which can potentially damage equipment, engines, and structures. Furthermore, with warm climatic conditions in most parts of India, conversion into electricity with cogeneration is not feasible and, as a result, system efficiency remains low.

Lack of adequate premium on 'green energy', uncertain payments from utilities and low priority due to small generation capacity are some of the institutional risk factors. Additional costs for odor control, biogas desulphurisation, wastewater treatment, supplementary fuel for duel-fuel engines, etc. further lead to lower operating margins. Lastly, the imported gas engines involve high capital costs and expensive repairs.

Combustion (mass burn/refuse derived fuel)

Low calorific value of feedstock, emission of toxins, limitations on industrial and domestic application of RDF, and inability to implement cogeneration are some of the main technical risk factors.

Typically the operating costs for supplementary fuel and emission control are major financial challenges. Secondly, capital cost of emission control (based on either 'maximum achievable control technology' or 'best demonstrated technology') turns out to be more than the main plant.

Reference: A case study of solid waste treatment and disposal technology options, Water and Sanitation Program, January 2007.

quantity of waste (e.g., the accepts) should be eligible for 'gate fee', rather than merely the rejects (conservatively estimated to be 20-30%) being given 'tipping fee'.

A SUSTAINABLE OPTION THAT ENABLES METHANE CAPTURE

Treatment of MSW is only a means to an end. The end objective of an integrated MSW operation is **safeguarding public health**, which can be achieved ultimately through safe disposal in a sanitary landfill. The apparently attractive paradigms of 'waste to energy' and 'waste to wealth' have been found to be unsustainable and are being reappraised objectively in light of cumulative international experience of several decades. Particularly for mixed MSW, international best practice is moving towards either sanitary landfill or mass burn (with maximum/best demonstrable emission control systems). In the Indian context, where the concept of sanitary landfill (SLF) is now well established, this Project Note attempts to bring out salient features and advantages of an advanced form of sanitary landfill, called **'bioreactor'**, which addresses many of the risk factors prevailing with conventional MSW treatment options.

A SLF, which is recognised as the most forgiving option for safe disposal of mixed MSW, serves as the base for a bioreactor. Unlike a treatment plant, a SLF/bioreactor is immune to a plethora of risk factors brought out in Box 2. Its potential for odor emissions and vector transmission is greatly mitigated as a result of daily spreading of a soil cover. A bioreactor builds upon basic landfill features by incorporating additional structural components and operational practices. It enhances the biological processes to transform and stabilize the readily and moderately decomposable organic matter within a period of five to 10 years and simultaneously maximizes production and capture of methane. This is achieved by blending of MSW with required additives (sewage sludge, dairy/slaughterhouse waste, other organics), maintaining optimum level of moisture (by recycling almost the entire quantity of leachate), and installing an active gas extraction system in the body of the landfill. Due to these features, a bioreactor is considered one of the most sustainable solutions offering the robustness and elasticity of a SLF and the advantages of a biogas plant.

A bioreactor precludes the need for setting up a potentially unviable processing plant and, due to an active gas extraction system, offers an advantage over a traditional SLF of reduced gas migration and potential damage to adjacent properties. Additional advantages comprise lower waste toxicity and mobility, improved leachate quality, reduced leachate treatment and disposal costs, a 15-30% gain in landfill airspace due to increase in the density of waste mass, reduced post-closure care, possibility of early land use following closure, and improved aesthetics compared to other treatment options.

WAY FORWARD

It is recognised that the MSW Rules, 2000, in their current form do not favor development of bioreactor technology in the country. While the Rules allow for disposal of mixed waste into a landfill when it is found 'unsuitable for processing', this provision is considered to be applicable only under 'unavoidable circumstances' or 'till installation of alternate facilities'. In view of the inherent rigidity in the MSW Rules, 2000, and the experience of the last seven years, there is a perceived need to make appropriate revisions in the Rules. The Rules should recognise inherent and fundamental limitations of the 'resource recovery' paradigm for mixed MSW beyond a certain point and offer avenues for development and implementation of sustainable options, which can guarantee safe and economical disposal of waste. In this regard, it is pertinent to state that instead of prescribing treatment technology options, which should be left to the facility planners, the Rules should only define standards for performance and environmental quality. It is hoped that existing anomalies will be adequately addressed in the ongoing revision.

The evolving solid waste management sector in the country will benefit tremendously from experience with bioreactors. It is desirable, therefore, that a set of pilots be allowed and attempted under favourable site and boundary conditions. The sector, which has already experimented with several promising, but highly risky technology options, should also be given a chance to experiment with a robust option which does not make unrealistic promises and guarantees public health and environmental safety at all times.

Asit Nema, Director of the Foundation for Greentech Environmental Systems, and Lee Baker, Chief of Party of the FIRE (D) project, wrote this *Project Note*. All *Project Notes* are available online at www.niua.org under *newsletters* and at www.dec.org under *title search* "FIRE (D) Project Note".

Indo-US Financial Institutions Reform and Expansion Project – Debt Market Component FIRE (D)

The mission of the Indo-US FIRE(D) Project is to institutionalize the delivery of commercially viable urban environmental infrastructure and services at the local, state and national levels. Since 1994, the Project has been working to support the development of demonstration projects and of a sustainable urban infrastructure finance system. Now, the Project is also pursuing this mission through:

- Expansion of the roles of the private sector, NGOs and CBOs in the development, delivery, operation and maintenance of urban environmental infrastructure;
- Increased efficiency in the operation and maintenance of existing water supply and sewerage systems;
- Strengthened financial management systems at the local level;
- Development of legal and regulatory frameworks at the state level;
- Continued implementation of the 74th Constitutional Amendment; and
- Capacity-building through the development of an Urban Management Training Network.

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