LANDFILL MANAGEMENT IN ASIA - NOTIONS ABOUT FUTURE APPROACHES TO APPROPRIATE AND SUSTAINABLE SOLUTIONS

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SUMMARY: The comprehensive output of research from China, India, Sri Lanka and Thailand is providing suggestion on how to produce a sound landfill technology in the Asian region. Primary focus has been given to the upgrading of the prevailing dumpsites, improving on first hand the reduction of both liquid and gaseous emissions. Further to that the future use of an upgraded location after rehabilitation considering land requirement and additional volumes for future sanitary landfills is considered and its pre-requisites are elaborated. Key technical issues addressed are based on the degradation in landfills and subsequent generation of landfill gas/leachate, and methane oxidation in landfill cover. In combination with these issues emphasis is given to simple and efficient pre-treatment technology like composting. The distinct influence of waste composition, monsooning conditions, and the needs to adopt design and operation are pondered

1. DOMESTIC WASTE MANAGEMENT IN ASIA

As rapid urbanization and economic development increases in Asia, nowhere is the impact more obvious than in society's "detritus," or solid waste. Nowadays, the urban areas of Asia produce approximately 8 million tones of municipal solid waste per day (World Bank, 1999). Open dumping is the most common solid waste disposal method in the region. The state of the dumping are, sadly, too similar: indiscriminately dumped, seemingly unplanned heaps of uncovered wastes, sometimes burning, pools of out standing polluted water, insects and rodent infestations, and families of waste scavenger picking up any valuables from waste (Pugh 1999). Furthermore, waste management is an essential task, which has important consequences for public health and well being, the quality and sustainability of the urban environment and the efficiency and productivity of the urban economy (Schubeler. et al, 1996).

In most cities of developing countries, waste management is inadequate: a significant portion of the population does not have access to a waste collection service and only a fraction of the generated waste is actually collected. Systems for transfer, recycling and/or disposal of solid waste are unsatisfactory from the environmental, economic and financial points (Schubeler. et al, 1996). Problems of shortage of cover, lack of leachate collection and treatment, inadequate compaction, poor site design, and many pickers working at the site are common. Thus, these dump sites are essentially uncontrolled, creating considerable health, safety, and environmental problems (International Source Book, UNEP, 2000).

When the prevailing situation is so critical there can often be tendency to apply the 'western way' of managing the solid waste related issues for better solution. Nonetheless, western approach in developing countries, uncritically and very rapidly resulting in malfunctioning facilities and inefficiently managed operations (Bodelius and Rydberg, 2000). Furthermore in developing countries, most local municipalities simply cannot afford the luxury of constructing containment landfills (Pugh 1999). Thus the prevailing conditions in these region demands comprehensive research on solid waste landfill management issues to improve significantly the protection of the local environment for a sustainable landfill management approach in Asian region.

2. REGIONAL SETTINGS

2.1 Waste composition and solid waste management

Treatment and disposal of MSW are basically depending on the composition of waste. The compositions of Asian MSWs greatly differ from Western industrialized world. Table 1 shows the average solid waste composition of MSW in various Asian countries in comparison to American and European data. It can be recognized that industrialized countries' waste consists of more recyclables and lower biodegradable organic waste whereas Asian waste is dominated by biowaste and in cases where mainly coal and wood is used for heating and cooking by a reasonable ash and dust fraction. Given these peculiarities the moisture content of Asian waste in general is comparable high in a range of 60-70% unless a high dust fraction is present. Therefore a very low calorific value of 4,000 - 5,800 kJ/kg is obtained. Additionally Asian waste is scavenged and in most cases deprived of any bulking agents. Consequently an immediate as well as intensive degradation takes place generating highly polluted wastewater and an immense nuisance. Thus a daily collection is common practice and source separation of high organic waste is not yet practiced. Shortcomings like insufficient collection coverage are common standard leading to waste littering and backyard/open space dumping.

Table 1 – Waste composition of various countries (Visvanathan et al 2003).

	Paper / cardboard	Textile	Leather / rubber	Plastic	Metal	Glass	Wood	Ash, dust others	Biowaste
China	6.9	4.7		7.3	0.5	1.6	6.9	19.2	52.6
India	7.6	4.7	1.3	3.8	1.7	2.1		40.1	39.6
Sri Lanka	12.3			6.8	3.7	3.0	10.2		64.7
Thailand	7.7	2.7	3.0	13.7	3.1	4.3	3.6	5.0	56.2
Europe (average)	32.0	4.0		7.0	8.0	10.0		9.0	30.0
USA (California)	41.0	2.4	2.6	10.7	7.9	5.8	5.0	0.5	24.1

2.2 Tropical climate impact

The influence of the climate on leachate production is complex: In relatively warm climates, like the region, the leachate production after precipitation is generally increasing quite rapid and leachate production is generally greater whenever, the waste is less compacted, since compaction reduces the filtration rate (Lema *et al*.1988). Consequently, it is significant to understand the effect of leachate generation and its characteristics due to the local climatic variations in the region on the landfill design and operation. In addition, seasonal variations can significantly affect the nature of MSW: in the rainy periods waste retains much moisture and is denser.

The South Asian Asia and Indo-China subcontinents fall into the northern tropics and belongs to dry and wet climates, where one monsoon brings most of the rainfall, while other one relatively dry. The main feature of the climates of these regions is the big difference in character of the monsoon winds. The summer monsoon generally brings warm and humid air masses, which produce large amounts of precipitation over 80 per cent during May to November. Winter monsoon mainly dry and cold and only few exposed coastal areas, where the winter monsoon arrives after long journey over sea, such as southeastern India, northeastern Sri Lanka and eastern part of Philippines islands experiences rain fall. In those areas, the summer monsoon is relatively dry.

In most of the Asian region landfill or dump sites belong to monsoon climate with extreme downpour for few months causing heavy leachate generation and a subsequent dry season with increased evaporation and less or no leachate generation. The dry season resembles a more aride climate and leachate generation might come to an entire halt. These contrary characteristics have to be taken into account designing as well operating landfill sites.

2.3 Open dump approach

In most Asian countries today, solid waste disposal still means dumping, for reasons such as ignorance (of the health risks associated with dumping of wastes); or acceptance of the status quo due to lack of financial resources to do anything better; or lack of political will, at all levels of government, to protect and improve public health and the environment. With the accelerated generation of waste caused by an ever-increasing population, urbanization, and industrialization, the problem has become one of the primary urban environmental issues (Ranaweera and Tränkler, 2001). Open dumping is a traditional and common disposal method at which solid wastes are disposed of in a manner that do not regard environmental and health impacts, is susceptible to open burning, and is exposed to the elements, disease vectors and scavengers. These unplanned heaps of uncovered wastes, often burning and surrounded by pools of stagnated polluted water, rat and fly infestations with domestic animals roaming freely and families of scavengers picking through the wastes is not only an eyesore but a great environmental hazard (Joseph et al, 2002). Most of the Asian countries are facing similar problems, e.g. in Thailand or India 70% to 90% of landfills are just open dump sites. However, land filling is considered to be the most effective method of solid waste disposal in developing countries if adequate sites are available. The closure as well as upgrading of existing sites is one of the most important steps towards sustainable solid waste management system (Ranaweera and Trankler, 2001).

3. LANDFILL DESIGN AND OPERATION IN ASIA

3.1 Sustainable landfill management - pre-requisites

The concerted investigations from various Asian institutions have revealed that the sustainable landfill management in Asia could be achieved from the following steps:

Dumpsite rehabilitation would be a paramount option to rehabilitate existing open dumps through landfill mining where the resource recovery might serve as a source of energy , recycle and reuse of metals, plastic and glass wares, use of compost as fertilizer for agriculture and as a cover material for future landfills. Because land close to the origin of the domestic is hard to be found dump site rehabilitation might benefit in regain a suitable site for an engineered landfill.

Pre-treatment of municipal solid waste prior to landfill through aerobic, anaerobic, and the combination of both shall become a must to reduce the total amount of waste to be disposed of and simultaneously diminish the leachate treatment, gas management, and geotechnical problem of landfill settlements.

The effects of pretreatment, compaction, and appropriate cover design would greatly minimize the pollution load to the environment. However, better understanding of the local climatic effect on enhance degradation would help accomplish the better landfill leachate management through adapted operational conditions to different seasonal variations. Focus has to be given on the interaction of design and flexible operation, which needs trained and experienced staff, too.

As environmental burden cannot be completely reduced biologically enhanced methane oxidation and combined biological and low cost chemical-physical treatment of landfill leachate is a final practice of open-ended aftercare.

3.2 Dumpsite rehabilitation by landfill mining

Within the category of MSW disposal, there are several options, which may be viewed as a stepwise progression towards state-of-the-art sanitary landfill. The first priority in most low-income countries should be to move municipal waste management onto the hierarchy, from widespread dumping to controlled disposal. Landfill mining is an option of exhuming existing or closed dumpsites and landfills, and sorting the exhumed materials for recycle, processing, or other disposition (Joseph, 2002). The objectives of landfill mining could be one or more of the following:

- Rehabilitation of dump sites and concerned environmental burden
- Redevelopment of landfill sites
- Conservation of landfill space
- Reduction in landfill area
- Elimination of potential contamination source
- Energy recovery from recovered wastes
- Reuse of recovered materials

Landfill mining uses the method of excavating and sorting the material from the existing site and using various processing steps in order to segregate the dumped waste. The success of materials recovery is dependent on the composition of the waste, the effectiveness of the mining technology and the efficiency of the technology. More important landfill mining from the existing and abundant open dumping site could be a positive opening for future landfill management and resource and energy recovery.

3.3 Pre-treatment prior to landfilling

The western strategies toward the municipal solid waste disposal are changing in the recent past due to very rich and strict rules and legislations. The developing nations are not in the same trend; nevertheless, it is necessary to focus on options for sustainable landfill management in future. The design of an appropriate landfill technology demands for a comprehensive approach on alternatives. Suitable and feasible landfill operations are most sought after and especially

those to curtail the post closure aftercare period. Thus it has become important to consider pre-treatment approach prior to landfill.

Biological pre-treatment of solid waste is claimed to have advantages such as shortening the monitoring period, production of better quality of leachate requiring less or no treatment, reduction in gas production rates and useful space in landfill due to better compacted waste (Ranaweera and Trankler, 2001). The most common pre-treatment practiced in the Asian countries would be composting and some places anaerobic biological treatment. However, the pre-treatment prior to landfill as an option is a new concept that has to be tested and be adapted to the local conditions. Especially waste composition and the climatic conditions are specific impediments, which have to be coped with. A transfer of sophisticated techniques will fail due to lack of means and skilled operators. Accordingly low-tech systems have a reasonable chance for application.

3.4 Leachate management

The Asian countries need to improve the criteria for liners and leachate collection systems to assure appropriate technology investments. The use of the *entombment* concept, questioned in the scientific community as unsustainable, should be carefully considered. In addition, the region must advance the concept of recirculation (with a secure bottom liner system, including the benefits and risks, the principles of simple treatment methods and their functions, and education of the principle of attenuation and dispersion. Many countries have national regulations requiring monitoring of leachate and groundwater but selected parameters are too many yet indicators are inadequate. Simple approaches with a few important indicator parameters may yield better results. For instance, monitoring chemical oxygen demand (COD), total nitrogen, and selected heavy metal levels may increase understanding of the pollution potential in the landfills and provide an early warning for groundwater contamination.

3.5 Landfill gas management

Anaerobic decomposition of municipal solid waste in the landfill generates large amount of green house gases and other trace gases. Landfills are estimated to account 25 % of the anthropogenic methane emission and 20 % of the total global anthropogenic methane emission (Ahn *et al* 2002). In Asia region, about 90 % of the open dumpsite without any top cover or preventive measures contributing to the methane emission from the MSW although shallow dump sites with layers of a few meter of waste generate less gases due a more or less anoxic status. The future controlled landfills and the engineered landfill have to incorporate design to reduce methane emission or oxidize the methane before entering the ambient environment.

Biological oxidation of CH_4 would be a choice as an inexpensive waste gas treatment mechanism of oxidation of CH_4 by indigenous bacterial populations. However, the enhanced biological oxidation of the landfill gas depends on the soil properties, bacterial population, moisture content, nutrient supplement etc. Thus controlling parameters are necessary to identified for a better landfill gas management under the given settings in Asian countries where the landfill gas recovery is not feasible due to size and the economical factors.

3.6 Landfill location, design and operation

Sanitary landfills in the industrialized countries are supposed to be built with optimized and adopted top and bottom liner systems, but most landfills in Asia are simply large but shallow holes in the ground filled with waste. Many of these landfills are located based on convenience rather than hydrogeology studies and consequently have been situated in environmentally

sensitive marshlands, abandoned mines, and river beds. Consequently locations of landfills have to be selected according to set hydro geological criteria with emphasis on monsooning conditions.

Decisions about the landfill construction have been taken without any kind of feasibility study and without assessment of the possible consequences of the landfill impacts, so far. Landfills have been designed without any environmental protection measures. National regulations in this region often set standards for environmental protection from landfills that are far above what can reasonably be afforded, and as a result, they are largely ignored. It is clear that changing from dumping to advanced standards of sanitary landfilling, cannot be expected overnight. The key to such change must be, with the benefit of today's scientific knowledge, the introduction of incremental improvements in the design standards of disposal, in step with the financial resources available. A transition from open dumping to sanitary landfilling would include intermediate stages that might be described as:

- Designated dumping (within a designated site, but with no control of operations);
- Controlled tipping (in a supervised site, with wastes disposed of in an organized manner in layers and covered periodically); and
- Dumpsite mining followed by landfill upgrading combined with pretreatment of MSW prior to landfill.
- Engineered landfilling (where the impact of wastes on the environment has been assessed and engineering measures taken to limit, but not necessarily eliminate such impacts).
- Leachate storage during rainy season and recycling during dry season similar to bioreactor operation to enhance the biodegradation.
- Top cover design with available and appropriate soil (eventually with soil amendments and compost mixture with suitable vegetations to enhance the methane oxidation release by the landfills and dumpsites.

Landfills have to be considered and designed as a structure withstanding natural forces of monsoon downpours as well as the desiccation during dry periods. Fundamental geotechnical information is missing and those systems applied in the Western hemisphere like HDPE liner or even clay liners might not be appropriate under the given settings. It is more likely that a seasonal combination of phased design and operation will provide optimum results.

Parallel to the upgrading of existing dumpsites disposal operation has to be adjusted. Up to now technology simply involved filling the hole with solid wastes, compacting if at all with a bulldozer, and covering with a layer of soil. Compaction in order to achieve low infiltration (especially during rainy season operation) and stability has to be implemented to the extent feasible. Up to now all kind of waste, including hazardous waste was buried together in the same landfill. Usually the waste disposal has not been controlled, i.e., neither amount of disposed waste nor origin and composition been registered. A variety of hazardous household and industrial chemicals – paint and solvents, pesticides, and many others – are likely to be found in municipal landfills. Finally more control of ingoing waste to a landfill and parallel hazardous waste management systems has to be established

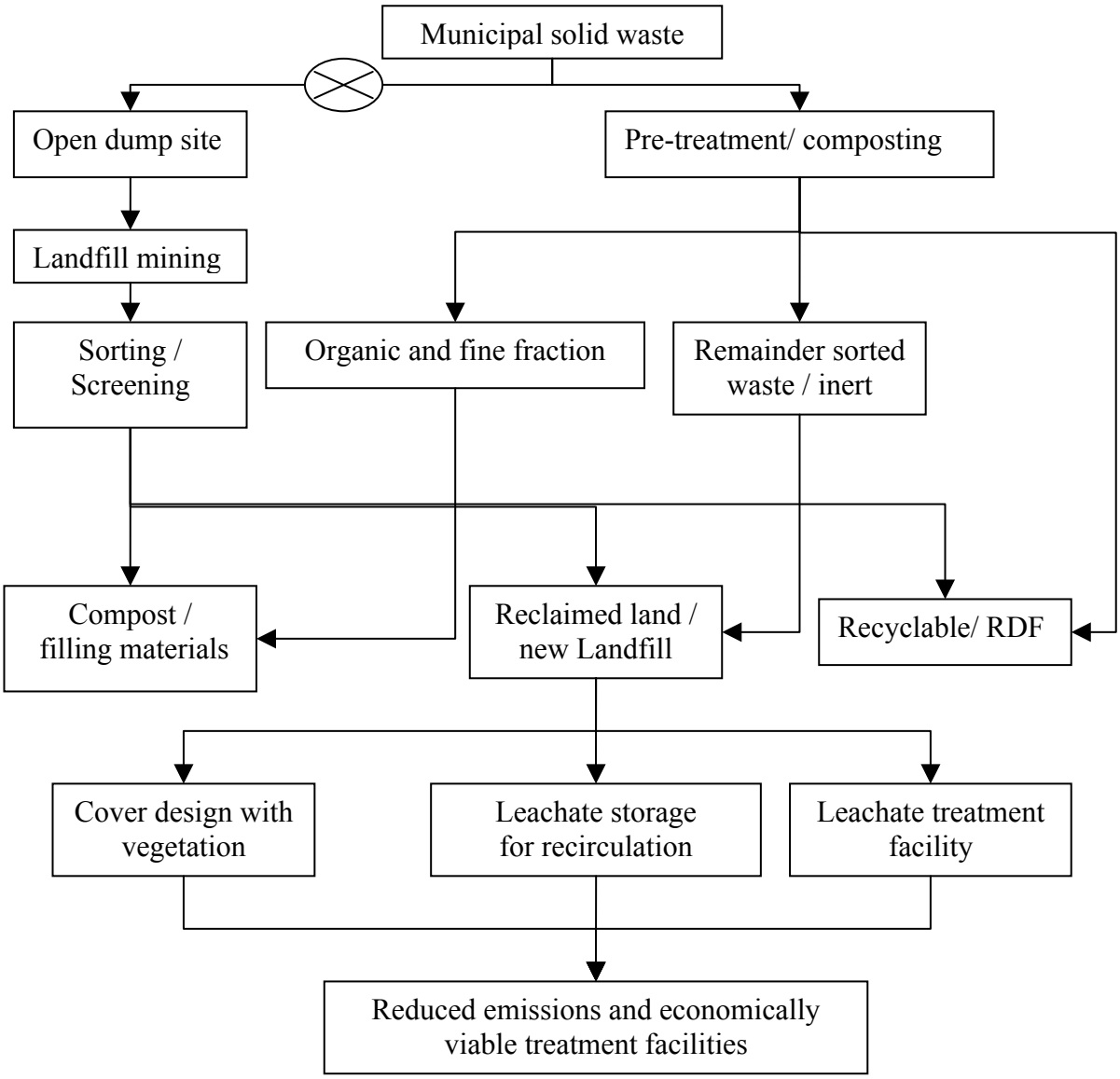

Figure 1: Sustainable landfill management approach in Asia.

Figure 1 show a sustainable approach of solid waste landfill management for Asian region where the tropical influences exist. The flowchart indicates the open dump land filling need to be stopped for better landfill management in future. The landfill could be upgraded to sanitary landfill of semi-engineered landfill.

4. SUSTAINABLE SOLID WASTE LANDFILL APPROACH FOR ASIA

Sustainable landfill management in Asian region can be a reality in the longer term. The emphasis shall be on a phased approach to the implementation of more sustainable processes which make up the desirability hierarchy of waste management in addition to solving immediate problems with high priority. The waste managers need the support of political leaders in this effort to achieve and maintain real improvements in the standard of service. The conversion of open dumps to sustainable landfills is an essential step to avoid future costs from present mismanagement. Considering the technical, institutional and economic situation of developing

countries, it is advisable to move from open dumping to sustainable landfills in a phased manner as appropriate to the location. The ultimate focus shall be on introducing integrated municipal solid waste management systems to minimize the demand for new landfills, maximize their lifetime, and recover resources from MSW.

ACKNOWLEDGEMENTS

The Authors wish to thank the Swedish International Development Agency (SIDA) for generously financing the research on "Sustainable Solid Waste Landfill Management in Asia" under the Asian Regional Research Program on Environmental Technologies

REFERENCES

Ahn Y. M, Nam K, Yoon S. P, Kim J Y (2002) Enhance methane oxidation technology by methanotrophs in solid waste landfills. In Proceedings of *2nd Asia Pacific Landfill Symposium*, Seoul, Korea, p.p 482 – 488.

Bodelius L. and Rydberg A. (2000) MSW management in China *Journal of Wastes Management*, 20, 4, pp 27-28

El-Fadel, M. et al. (1997); Environmental impacts of solid waste landfilling. *Journal of Environmental Management*, 50,1, 1-25.

International source books, UNEP, Newsletter and Technical Publications http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/RO/Asia/Topic_e.asp

Kurian Joseph, Nagendran. R and Palanivelu K (2002), "Open Dumps to Sustainable Landfills", CES ENVISION, Monthly newsletter of the ENVIS node under EMCBTA project at CES (AU/CES/NL-02) supported by Ministry of Environment and Forests, Government of India, Vol.1, No.2

Nieuwolt. S, (1978) Tropical Climatology, John Wiley & Sons, p. 129-147.

Pugh M. (1999) "The path to affordable landfills", *Journal of Waste Management*, October 1999, pp. 58-59

Rushbrook, P and Pugh, M (1999): Solid Waste Landfills in Middle- and Lower-income Countries: a Technical Guide to Planning, Design, and Operation. World Bank Technical Paper No 426, 1999.

Schubeler, P. et al. (1996) "Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries." Urban Management Program Working Paper No. 9, World Bank,

Visvanathan C., Kurupan P., Norbu T., Tränkler J., Basnayake B.F.A, Chart Chiemchaisri, Kurian Joseph, and Zhou Gonming (2003) Comparative Study on Municipal Solid Waste Management in Asia, in print, Asian Institute of Technology ARPPET reports

World Bank (1999)," What a waste – Solid waste management in Asia" Urban and Local Government Working Papers, The International Bank for Reconstruction and Development/THE WORLD BANK, 1818 H Street, N.W. Washington, D.C. 20433, U.S.A.