Dumpsite Rehabilitation

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Abstract- *The objectives of this journal are to ensure that the open dumps are fully characterized, investigated, remediated and closed properly and to assure public health and safety. Primary focus was given to the upgrading of the operating/existing dumpsites, the most common practice of waste disposal in Asian countries. Open burning, stagnant pools of polluted water, infestations by rats and flies, scavenging by domestic animals and rag picking through the wastes by scavenging community are a common sight. The presence of waste pickers has a major impact on the operation of the dumpsite as they pose a safety hazard not only to the scavengers but to the dumpsite employees as well. It reduces the efficiency of waste disposal due to the interference with operations at the tipping face and starting of fires by the scavengers, which cause air pollution problems. When used appropriately, the process described in this journal will help to ensure that a good strategy is developed and implemented effectively.*

Keywords- Landfill, Solid waste, Rehabilitation, Leachate, Dumpsite, Reclamation, Sustainability.

I. INTRODUCTION

Land filling is the most common and environmentally safe method of disposal for the fractions of municipal solid waste (MSW) that cannot be reduced, recycled, composted, combusted or processed. Open dumping of MSW, which is practiced by about three-fourths of the countries and territories in the world is a primitive stage of landfill development (Rushbrook, 2001). The open dumps or dumpsites cause degradation of the environment since they are susceptible to open burning and exposed to scavengers and disease vectors. Most often dumpsites are poorly sited and operated by technically inexperienced staff.

Dumpsites in Asian countries are similar and characterized by indiscriminately disposed heaps of uncovered waste. Open burning, stagnant pools of polluted water, infestations by rats and flies, scavenging by domestic animals and rag picking through the wastes by scavenging community are a common sight. The presence of waste pickers has a major impact on the operation of the dumpsite as they pose a safety hazard not only to the scavengers but to the dumpsite employees as well. It reduces the efficiency of waste disposal due to the interference with operations at the tipping face and starting of fires by the scavengers, which cause air pollution problems.

There are a number of major risks and impacts of the dumpsites on the environment. The leachate generated as a result of decomposition of waste contaminates surface and groundwater sources which become unfit for human consumption. Air pollution from open burning, fire hazards and explosions cause public health risks as well as add to the emission of greenhouse gases (methane and carbon dioxide). Scattering of wastes by wind and scavenging by birds, animals and waste pickers creates aesthetic nuisance. Malodour emanating due to the degradation of the waste in the dumpsite restricts land use development as it decreases the economic and social values in surrounding areas. The absence of daily cover on the dumped waste attracts the animal and human scavengers alike.

The environmental and health impact of improper MSW disposal practices in opendumps can be reduced by dumpsite rehabilitation. This may be defined as a process by which disposed wastes in an existing dumpsite is excavated and either reused or disposed in an environmentally friendly manner. Excavated waste may require to be moved or relocated to higher portions of the site or placed in appropriate areas to enable an adequate gradient for the closed site.
Dumpsite rehabilitation projects are initiated due to one of the following reasons:

- **(i)** Presence of marketable material in the dumpsite that can be excavated for sale or use;
- **(ii)** Reduction in the closure and post operation monitoring costs of the site;
- **(iii)** Stipulated requirement by the owner/regulator of the landfill to close and rehabilitate the site; and
- **(iv)** Presence of toxic wastes within the dump site that poses public health risks.

The process of rehabilitating a dumpsite to a sustainable landfill may be done in a phased manner depending on the risk posed by the dump and its financial aspects as well. The key to enable such a change depends on today's scientific knowledge and the introduction of incremental improvements in the standards of disposal in line with the available financial resources (Rushbrook, 1999, 2001). The following sections of this chapter present a phased approach to the rehabilitation of dumpsites with a few case studies in India to highlight the progress in this direction.

II. PHASED APPROACH TO DUMPSITE REHABILITATION

Developing countries suffer from limited available resources for upgrading or relocating open dumps. They also do not have adequate funds and technical competence to operate and maintain engineered solid waste disposal sites. It may not be possible for these countries to immediately attain a level of highly complex landfill design and construction as practiced by the developed countries. Therefore, the improvement of disposal practices could only be achieved by a step-by-step approach (Rushbrook, 1999, 2001) from open dumps to controlled dump, engineered landfills and sustainablelandfills.

CONTROLLED DUMPS

The first step in upgrading open dumps involves reduction of environmental nuisances like odor, dust and infestation by vermins and birds. Controlled dumps are operated with basic inspection and recording of incoming wastes, monitoring of the tipping front, compaction of waste and application of soil cover. It is one step better than open dumping with certain basic control measures that include designating an authorized person at the site who controls the accessibility of vehicles and the type of waste being disposed at the site. Supervisors designate specific sites for tipping of wastes in a controlled pattern. Basic handling techniques are used to consolidate the waste and eliminate open burning, foraging by animals and controlled salvaging operations by waste pickers. Preliminary drainage control measures are used to manage leachate flows and storm-water runoffs from the sites.

In order to achieve these improvements from open dumping system to controlled dumps, an appropriate combination of simple techniques is used. This may be accomplished by fencing of the site and provision of security personnel to control scavenging, monitor vehicles, control entry of stray animals and prevent open burning. Other methods used are provision/improvement of access roads, diversion of runoff with adequate drains, provision of sign and direction boards, monitoring of incoming vehicles and waste characteristics, planning of the tipping sites, and zoning for special waste disposal. Certain appropriate equipments and machinery are required for effectual operation. The management would maintain an office with records of waste disposal and monitor the safety aspects of the workers by providing adequate gears.

FENCING

The main purposes of fencing a dumpsite are to control access to the disposal site and curtail open dumping, manage uncontrolled scavenging by waste pickers and to protect the vegetated sites. As a minimum requirement all open dumpsites within 500 meters of communities should be fenced. Perimeter fencing is desirable around all rehabilitated open dumpsites though it may not be practical. It helps delineate the site boundary, discourages unauthorized vehicular access and prevents entry of stray animals. However, simple fencing will not deter scavengers from entering a site. The perimeter at both sides of the site entrance should be fenced sufficiently to prevent vehicles bypassing the official entry point. The minimum form of fencing to control vehicular access and larger animals would be a stake-and-wire strand (barbed-wire) fence or an excavated perimeter ditch and bund planted with fast growing hedge-forming shrubs.

After closing the site to public access, the facility and the surrounding areas should be cleaned up so that any waste pile and windblown paper/plastic are collected and placed in a final disposal cell for covering. Particular attention should be given to any environmentally sensitive areas where waste might have been placed in or next to wetlands, piled with a steeper slope or placed in areas of natural drainage or impede surface water flow. The requirements are relatively simple and inexpensive for which local enforcement agencies should consider enacting appropriate ordinances and legislative provisions that prohibit unauthorized disposals.

SCAVENGING CONTROL

Scavenging is practiced in all municipal dumpsites by economically backward communities who collect valuables from the waste and makea living. This activity hampers controlled and safe operation of solid waste disposal sites and should be banned ideally due to the deleterious circumstances to the scavengers. Complete banning of scavenging would require additional site security measures, increased landfill volume, and loss of recyclables as well as it would be economically damaging to the scavenging community. To accommodate the scavenging activities without interfering with the waste emplacement operations, a policy is required.

Where controlled scavenging activities are tolerated, the scavengers should be separated so that the work of the mechanical equipments used for emplacing waste would not be hindered. A temporary scavenging area could be set up near the waste disposal area where trucks discharge their loads. Once the scavengers have finished retrieving the valuables, the waste is bulldozed to the emplacement area. At larger dumpsites, a permanent scavenging area (raised platform) could be established and after their operation, the residues could then be transferred for transport to the emplacement area. One common method is to arrange a scavenging licence for families or groups of scavengers to enter the dumpsite for picking the valuables.

ACCESS ROAD

A sufficiently wide access road to a disposal site from the highway is essential to enable the passing of two trucks travelling in opposite direction. The road should be upgraded to service the dumpsite in all seasons to a standard that enables easy passage of trucks carrying waste to the site. At the same time, dumping of the waste on the road side should be banned and the callously dumped waste on the road sides need to be cleared. A minimum standard for the road surface is compacted earth or similar material with a top dressing of gravel to enable a firm running surface. A durable asphalt surface would be preferred if resources are available.

FIRE CONTROL

Dumpsite fires are commonly set by the scavengers to recover metallic wastes. To eliminate this hazard, a plan would be required to extinguish fires and prevent future occurrences as the rehabilitation work progresses across the site. Use of water to extinguish fires should be avoided while isolation and rapid natural burnout or smothering with soil is preferred.

LAY OUT

The layout of the controlled dump is strongly influenced by the site’s geology. The potential for gas and leachate migration and the suitability of the soil for landfill base and cover material are crucial. Site layout relates closely to the geotechnical information - data on stratigraphy, hydrology and soil structure. These data are usually collected during the site- selection and investigations as these are required for the design and functioning of the dumpsite.

SLOPE STABILITY

The slope of waste filled portions is a primary concern as adequate gradient is required to promote surface water runoff without ponding or water-logging or erosion of the final cover. The grade of the land and the length affects slope erosion. The final slopes of the filled portions of the site should be 2 - 8% in grade and should not exceed the upper limit.

Over-steepened waste slopes should be identified for regrading with estimations of the quantity of waste to be removed. Unless local geotechnical reasons prevail in the site and cannot be adjusted, the waste side slope should not be steeper than 1 in 3 and top slopes should not be more than 1 in 20 (Rushbrook, 2001). Slope stabilization activities should seek to redistribute waste within the confines of the existing dumpsite without extending the external boundaries of the fill.

SURFACE DRAINAGE

It is important to promote surface drainage in landfills to keep off the surface runoff from percolating through the garbage and solubalising the wastes to form leachate, which degrades surface and ground water quality. If leachate accumulation is identified in an open dumpsite, a plan should be made to either drain or pump it into a constructed lagoon (not liable to flooding) or even can be recirculated back into the waste. Leachate source should be determined to carry out remedial works that help to prevent future leachate accumulations.

MECHANICAL EQUIPMENT

During the preparations for dumpsite rehabilitation, mechanical equipments should be provided in order to serve three basic functions that are essential for a controlled disposal which are related to soil, waste and support activities. The functions at the site include excavation, handling, spreading and compaction for soil and wastes, maintenance of on-site haul roads, pumping of water or leachate, making of drainage ditches and removal of trapped lorries from the landfill working area.

The required number and type of equipment varies and depends on the quantity of waste handled daily together with the available resources to operate and maintain the equipment. The most essential equipment for the full-scale operation of the disposal site are:

- **(i)** One bulldozer of adequate capacity to handle the daily quantity of waste arriving at the site for spreading and compacting it and providing it soil cover; and
- **(ii)** One tractor with trailer to haul cover soil to the work zone and undertake other support activities.

To facilitate the smooth operation and maintenance of the machinery, a supply of spare parts and consumable items are necessary while a supply of hand tools such as shovels, brooms, wheelbarrows and rakes are required for any manual work.

SOIL COVER

Once the landfilled areas have been sloped and all the waste compacted and covered, the site should be covered with at least 60 cm of clay-rich soil. This final cover of clay-rich soil should have an inner layer (about 30 cm for inert waste landfills or 45 cm for municipal solid waste landfills) compacted in lifts of 15 cm to minimize surface water infiltration. Compaction testing of this barrier layer may be required to ensure proper placing of the soil. An additional 30 - 45 cm of soil should be placed over the compacted clay layer to protect it from erosion, plant roots, vehicular traffic, etc. This buffer layer also provides a rooting depth for the final foliage cover.

Compared to the benefits of a better-controlled operation and improved compaction of waste, soil cover is expensive and may not be significantly beneficial for a dumpsite located in a remote area. For a limited dumpsite volume, use of soil-cover decreases the available site volume for waste disposal. In the event of a decision to use cover material, the daily quantity should be estimated (based on 5 cm of daily cover, 25 cm intermediate cover and 50 cm final cover).

Controlled dumps have only limited measures to mitigate environmental impacts. There exists unmanaged release of contaminants due to inadequate precautionary measures for leachate and landfill gas management. This is relevant where the produced leachate cannot be retained by the underlying permeable rock layer or fissured stratigraphy. This concern may be less critical in semi-arid and arid climates where leachate is not generated from dumpsites in measurable quantities and can be controlled in an engineered landfill.

ENGINEERED LANDFILLS

Landfills that have waste compaction and application of soil cover on a daily basis to reduce nuisances are called engineered land fills. They incorporate technological measures to control gas emissions, have provisions for leachate collection and treatment, and daily soil cover on the waste layer. Each landfill implements closure and post-closure monitoring plans. Whatever the climatic and hydro- geological environment, leachate management for conventional landfills require placement of liners (often composite liner systems), and leachate collection and treatment plants. Leachate treatment methods range from advanced physicochemical and biological treatment sequences to the development of pond treatment and enhanced evaporation techniques. Recirculation of leachate could also be practiced with its storage and eventual evaporation. The essential elements of an engineered landfill and their functions are presented in Table 1.

TABLE 1. THE ESSENTIAL COMPONENTS AND THEIR FUNCTIONS IN AN ENGINEERED LANDFILL.

COMPONENTS	FUNCTIONS
Liner system	Placed at the base and sides of the landfill, it prevents migration of leachate or gas to the surrounding environment.
Leachate collection and treatment system	The system extracts and collects leachate from within and the base of the landfill and treats it to meet the regulatory discharge standards.
Final cover	Enhances surface drainage, prevents infiltration of water and supports surface vegetation.
Surface water drainage	Collects and removes all surface runoff from the landfill site.
Environmental monitoring system	The system periodically collects and analyses air, surface water, soil and ground water samples around the landfill site.
Competent Workforce	Organizes landfill operation and maintenance activities and maintains a detailed record keeping system.
Monitoring	Organizes landfill closure and post closure monitoring of the site

Thus from the above, one can conclude that there are several steps involved in converting a controlled dumpsite to an engineered landfill. Initially, an estimate of the landfill volume requirements is made, based on which, investigation and selection of potential sites are carried out. The filling plan is then designed based on the requirement with the incorporation of a leachate management and gas management plan and preparation of the final cover. Provisions for monitoring surface and groundwater are also included in the plan. The planning aspects further requires approvals from the concerned authority for which methods for operating the landfill, organizing its closure and post-closure care need to be outlined.

The approach described above can be called “dry tomb” system which is aimed at minimizing infiltration and percolation of water into the waste layers. Though this approach reduces the volume of leachate produced, it slows down the biodegradation process and prolongs the potential hazard of the waste for a long time. The entry of water into the dry tomb would cause the failure of the encapsulation and consequently foster leachate generation.

SUSTAINABLE LANDFILLS

Engineered landfills represent a short-term approach for waste disposal by those who generate it today and postpone groundwater pollution for the future. Though this approach has lesser solid waste management costs, a part of the true costs are however, passed on to the future generations.

Sustainable management of municipal solid wastes would require of those who generate them to pay until the wastes are stabilized to a final storage quality.

The traditional model of a landfill as a permanent waste deposit in which decomposition processes are minimized is giving way to the concept of a controlled decomposition process managed as a large-scale bioreactor. This controlled bioreactor landfill is seen as a flexible, cost effective and sustainable approach to current waste disposal problems particularly when it is combined with material recovery either before or after biological treatment. Thus, it may no longer be necessary to view landfilling as a final disposal system but rather as a method for large-scale processing of waste that combines recovery and recycling processes.

In sustainable landfills, airspace, processes, control and/or use of products and residues are at an optimum with minimal negative effects on the environment. The goal is to treat the waste within a lifetime. This is achieved after the waste becomes stabilized within a landfill and it can be mined to make the space available for refilling (ECS, 2001). Landfill mining in a sustainablelandfillshould beattempted when thelandfilled wastesaresufficiently stabilized. The attainment of this level depends to a large extent upon the parameters that control the chemical and biological processes (moisture content, temperature, microflora and compaction rate) occurring in the landfill waste (Zurbrugg, 1999). Two new methods of landfill disposal often called the anaerobic bioreactor and the aerobic biocell are attempts in this direction (Reinhart and Timothy, 1998).

The wet-cell approach involving clean water washing of the garbage to remove leachable components after stabilization with respect to landfill gas formation that may produce a residue within 10 - 20 years presents little threat to groundwater quality. This *in situ* treatment period is expected to be within the effective lifetime of the liners used at the base for leachate collection and removal system in asingle composite lined landfill. For effectiveness, high quality construction is required for the landfill liner system such that holes or unusual stresses are not placed on the landfill liner system during the deposition of wastes.

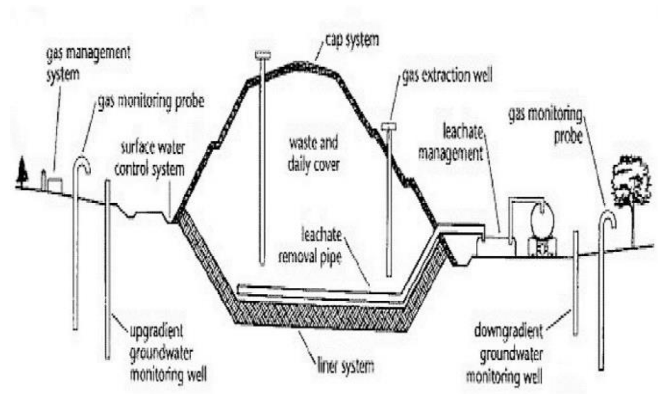

FIGURE 1 SCHEMATIC OF SUSTAINABLE LANDFILLS (ECS, 2001)

A sustainable landfill necessitates adequate attention to all the technical aspects of landfill development which are siting, design, operation, prevention and monitoring of long-term environmental impacts. In principle, operating techniques vary only slightly (e.g., thickness of the layer in which waste is compacted, the amount of daily soil cover applied, the organization of tipping fronts) and are typically influenced by landfill management. Leachate control and management approaches on the other hand, can vary significantly. Figure 1 gives a schematic of sustainable landfills.

III. PLANNING DUMPSITE REHABILITATION

Dumpsite rehabilitation has distinct stages of remedial activity which can be enumerated as:

- **a.** Planning and designing the remedial works;
- **b.** Undertaking one-time physical improvements at the site; and
- **c.** Changing of subsequent operations at the site.

The first task would be to decide if the site should be closed, remediated or rehabilitated. To determine whether to rehabilitate and close or remediate, upgrade and operate a dumpsite, the environmental risks posed by the site must be assessed. These may involve technical investigations and environmental impact assessments (EIAs) including consultation with the interested and affected parties, specifically the adjacent communities.

The first step in planning should be a site survey to gather specific information such as its operating history, types of wastes disposed its dimensions, topography and physical characteristics (Salerni, 1995). The next step for site investigation involves planning for preliminary excavation and obtaining the necessary regulatory approvals. At this point, a work plan must be developed which includes the number of pits and/or trenches to be dug; equipment and material handling procedure; labour requirements and their safety issues; creation of a work zone with clearly marked boundaries; and necessary analytical testing, measurements and collection of data.

The feasibility studies and work plans for dumpsite rehabilitation include a preliminary site investigation followed by a detailed fieldinvestigation.

PRELIMINARY SITE INVESTIGATION

Site inspection, personal interviews, review of landfill records and study of the site history are done during this stage. The investigation must include the following:

- Description of the vertical and area extent of the site and how it can be delineated into sections, trenches, cells, berms or other diversions to form discrete or partially separated areas for special waste (sewage sludge, ash, asbestos waste, construction and demolition debris etc.) disposal areas.
- Description of the age, type of waste and cover material, landfill operation method and estimation of volume for each area of the landfill identified above based on the thickness of solid waste fill.
- Estimation and evaluation of the water table depth throughout the area to be rehabilitated should be made vis-à-vis the existing ground water monitoring system, procedures and availability of the most recent analytical data.
- Assessment of available work space for equipment storage and other work areas.
- Field work and laboratory analysis that is a part of the feasibility study.
- Description of the regulatory status of the landfill (e.g., results of regulatory inspections, compliance history, permit status, etc.);
- Description of the owner/operator's future plan for the landfill after reclamation;
- Characterization of excavated materials (e.g., recyclables, combustibles, reusable soil, rejects, and other components) based on which suitability evaluation of the excavated material for reuse, recycling or further processing and expected final disposition can be made.

FIELD INVESTIGATION WORK PLAN

This involves description of the required field work and laboratory analysis that is a part of the feasibility study. The work plan includes all proposed work areas where all borings, trenches and test pits would be located along with their numbers, estimated depths and volumes. It further gives a description of all excavations and material handling operations. It describes material quantification methods, laboratory analyses and test burns that would be used to characterize and estimate the quantities of recyclables, combustibles, reusable soil, rejects and other components. Finally, the plan delineates project management responsibilities and the proposed work schedule.

This plan would provide the blueprint for every activity to be conducted during site investigation. The primary activity of the site investigation is to characterize the wastes in the areas to be excavated. This is accomplished by digging test pits and/or trenches and analyzing to determine material volumes, soil to waste ratio, waste composition and its state of decomposition. A trench exposes a larger area and can give a better idea of what is buried than digging a pit but may unleash odours (Salerni, 1995). Once the site investigation is completed, the information gathered should be analyzed to determine whether the proposed goals could be met within the projected cost framework. The issues to be addressed in this analysis include slope stability, access roads, leachate management, fire control, soil cover, waste reception, fencing, scavenger control, use of mechanical equipments, limiting the working face and waste disposal operations.

A site visit is necessary to characterize the extent of the wastes and the condition of the cover. During the site visit, it is important to record the depth of wastes, the depth of ground water table and that of any perched water zones in order to identify water saturated waste areas. Estimates of dump’s horizontal extent and depth usually reduce the number of excavations and borings needed to determine the extent of the waste materials and facilitate more accurate estimates of the cost of investigation and remediation.

Generally, little information would be available on the type of materials disposed of in dumps and separation of wastes is not a common practice. Often industrial and hazardous wastes are also disposed of in such dumpsites. Limited information concerning the waste types may be available from existing records or with interviews of nearby residents and individuals who had worked during disposal of wastes in the dump.

If the dump cover is poor or sporadic, a walk over of the dump area could provide information on the types of wastes. Trenches and/or soil borings are generally used to retrieve waste samples for characterization. Trenches generally produce more usable information since a larger, continuous area is exposed. It enables better recovery of whole items giving a better indication of the types and condition of the waste materials, the consistency of the soil cover and evidence of soil/waste layering.

Soil borings, being less intrusive can only retrieve a small portion of the wastes for examination. While soil borings alone may fail to fully characterize a dump, they havethe advantage of producing less odour, can cover a larger area in lesser time and can be located closer to buildings without endangering their stability. Observations of dumped materials include listing the presence of liquids, semi- solids, ash, cinders and solid chemicals such as paint and resin. Any evidence of decomposition, visual contamination, odours, perched water, leachate, moisture or hazardous substances should be noted. Lists of items encountered, relative amounts of wastes and soil and conclusions drawn up regarding relative amounts of household, municipal, industrial and demolition materials are important in characterizing dumps. Photographs of trenches and excavated wastes are extremely useful in documenting waste materials. It is recommended to prepare vertical profile logs.

After determining the nature of the materials, health and safety issues, and possible impacts to the environment of the dumpsite, concerned regulatory agencies should be contacted and the wastes should be stockpiled separately from non-impacted soils. Wastes should be sorted based on physical appearance (texture and consistency), field screening response and incidental odours. Waste/soil segregation is dependent on waste management options. Separate waste piles may be made for soil, recyclables, demolition materials, scrap metals, general municipal solid waste and suspected hazardous wastes, land fillable materials, containerized chemical wastes, contaminated soils and special wastes. Questionable or suspicious hazardous wastes and contaminated media should be separated from all other category of wastes.

The dumpsite rehabilitation process is to be planned with respect to the needs of the operation period. The site may be divided into a number of phases to allow continuation of operation while site preparation and other rehabilitation components can be started simultaneously. Site preparation involves reshaping and covering the surface of the existing waste body with an intermediate cover. Each operation should be conducted in a manner which prevents the discharge of material or pollution of surface or groundwater, air or land environment in accordance with the national/local regulations. Operations should be conducted in such a manner to ensure that uncovered hazardous constituents are properly handled and timely disposed of in an authorized facility. Figure 2 illustrates the sustainable landfill reclamation process.

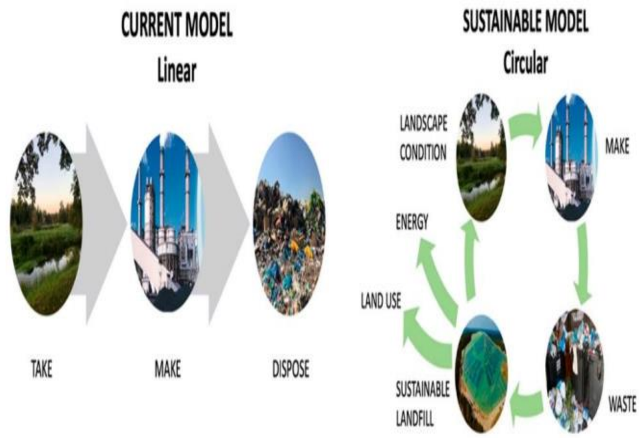

FIGURE 2. SUSTAINABLE LANDFILL RECLAMATION PROCESS (THERMOGENICS, 1999)

All on-site roads should be watered or paved and cleaned when necessary for maximized control of dust emissions. All material should be conveyed mechanically. Excavated waste material from the landfill site should be transported in covered trucks to minimize loss. Leachate should be contained in lined retention facilities until its further handling. The facility should be designed and operated to prevent potential nuisance conditions and fire hazards. The test pit evaluation report should be prepared by an engineer. Prior approval of a test pit plan must be obtained from the regulatory authorities before excavating them including their locations and depths. The application should include a discussion and information on the following regarding the description of the characteristics of waste in excavated test pits (percentage weight of paper, plastics, ferrous metals, other metals, glass, other constituents and soil fraction).

The test pits should extend at least 1 metre beneath the waste or to a depth authorized by the regulators and the information should include the leaching procedure of the soil to characterize the soil beneath the site. Consideration should be given to the analysis of waste material from each test pit for hazardous waste constituents. A sufficient number of test pits (three for a site of five acres or less) should be used to establish the general properties of the waste. For sites larger than five acres the number of test pits should be one for every five acres or its fraction in addition to the three pits. These test pits should be sufficiently large to provide representative information. The test pit evaluation report should address historical records of landfill operations where available. It should be evaluated to determine the types of waste received, hazardous waste potentials, receipts of special waste and their disposal areas, construction and demolition material disposal areas, methane emission and leachate records, age of the landfill, volume and disposal methods, presence of liners, gas and leachate collection systems.

There are other important issues to be addressed which are security, site access control, traffic control and safety. Control of dumping within designated areas, screening for unprocessable or unauthorized material should be taken up. Prevention of dumpsite fire should be based on the control plan that would comply with the provisions of the local fire code. Provision for fire-fighting equipments and requirements of special training for fire fighting personnel are other key safety issues. In addition, control of windblown material, vector control, quality assurance and quality control are equally necessary.

3.1 OPERATIONAL PLAN

The operational plan should address future landfilling issues which should be restricted to non-biodegradable inert waste and other wastes unsuitable for recycling or biological processing. Landfilling should also be carried out for residues of waste processing facilities as well as for pre-processing rejects from the waste processing facilities.

All exposed and uncontrolled piles of waste should be compacted into layers. They may also be moved to other parts of the site if this facilitates the creation of the eventual final landform of the site. All uncovered areas of waste where new deposits are not expected within the next few months should be covered with an intermediate or final layer of soil. The remaining area of exposed waste then forms the initial working area for the emplacement of the incoming waste. This area should not exceed 0.5 hectares for sites receiving up to 250 tons/day and one hectare for sites receiving 250 - 500 tons/day. Two hectares may be appropriate at larger sites receiving well over 500 tons/day. A daily review of the work plan is necessary to make adjustments to suit siterequirements.

Waste disposal operations at the site should be in accordance to a disposal plan prepared during rehabilitation planning. At the site entrance, all incoming loads should be registered with records of details like date, time of arrival, vehicle identification number, vehicleowner, description of waste, estimated quantity of waste (weight or volume) and the waste emplacement area used. The waste disposal site should have a sign at the main entrance that gives its details (name, opening days and hours, arrival instructions for drivers, no smoking markings, etc.) and a short summary of its importance.

The site staff should be trained and provided with well-defined roles and responsibilities for an organised and effective waste disposal operation. Status, pay, employment, contracts and working conditions also influence the ability and willingness of individual staff members to accept and carry out their responsibilities.

IV. DUMPSITE REHABILITATION CASE STUDIES

Landfill reclamation and rehabilitation have been used throughout the world during the last 50 years as a tool for sustainable landfilling. This is popularly known as Landfill Mining. It is the process of excavating from operating or closed solid waste landfills and sorting the unearthed materials for recycling, processing, or for other dispositions. The first reported landfill mining operation was in Tel Aviv Israel in 1953, which was used to recover soil fraction thathelped improve the soilquality in theorchards (Shual and Hillel, 1958; Savage *et al*., 1993). It was later employed in United States of America (USA) to obtain fuel for incineration and energy recovery (USEPA, 1997; Hogland, 1996, Cossu *etal*., 1996, Hogland *etal*., 1996). Pilot studies carried out in England, Italy, Sweden, Germany (Cossu *et al*., 1995; Hogland *et al*., 1995), China and India (Joseph et al,2003) are also reported.

CASE STUDIES FROM INDIA

4.1.1. URULI DEWACHI, PUNE

The city of Pune in India generates approximately 1000 tons/day of MSW. Like most other municipalities, Pune Municipal Corporation (PMC) has been dumping the MSW in open land and abandoned quarries. One such site, a stone quarry is in the village of Uruli Dewachi about 5 - 6 km from PMC boundary off the Saswad road. The waste coming to the site was about 750 tons/day and the site has been closed for the last 4 years. When serious groundwater contamination was observed from wells 2 km downstream, PMC adopted a strategy of rehabilitating the dumpsite by capping it and constructing a sanitary landfill over the capped site (Purandare, 2003).

The task of rehabilitating the dumpsite was undertaken by M/s Eco Designs India Pvt. Ltd., Pune in February 2002. The preliminary design included closure/capping of the existing dumpsite, designing a landfill above the capped waste adequate to handle one year’s MSW; and designing in parallel another landfill adjacent to the capped site to serve PMC for the next 5 years.

The waste had been randomly deposited without any spreading or compaction. A preliminary inspection found that the waste heap was very unstable primarily because of the face angle of the waste, which was in excess of the stable angle of repose. It wastherefore necessary to change the slopes as well as compact the waste so that it would be stable. The waste was evenly spread out and compacted on the slopes and the top by heavy duty bulldozers. The enclosure covered an area of about 34,600 m^2 and the depth of waste layer was as much as 18 m at the edge even after proper levelling.

Once the waste was graded and compacted, a 0.75 mm thick very flexible polyethylene (VFPE) liner was installed above it to prevent infiltration of rain water. This was protected with a geotextile overlaid by 300 mm thick soil layer. The soil layer was finally covered with sweet earth for planting grass and preventing erosion of the cover soil. Drains were provided on the slopes to drain storm water and collect it at the bottom, where a gutter along with a toe wall was built. Gas vents allowed the release of gases that could potentially be formed within the covered landfill (Joseph et al, 2004).

4.1.2 PANKI, KANPUR

Kanpur, an important industrial city of Uttar Pradesh, India located at the bank of the river Ganga, is spread over an area of 299 km^2 with an estimated population of 3 million. An estimated quantity of 1000 t/day of MSW is generated from the city out of which about 700 t/day is collected and disposed in dumpsites. Panki site, the only active site in Kanpur, is spread over an area of 8 hectares and has been serving the municipality for the past 10 - 15 years. The average height of the waste is about 4 - 5 metres above the ground level. New Delhi based National Productivity Council (NPC) was engaged by the local authorities to assist the upgradation of this dumpsite. NPC then suggested its site upgradation plan based on a detailed environmental impact assessment (Saxena and Bharadwaj, 2003).

V. CONCLUSION

At present, there are only limited resources for upgrading or replacing the dumpsites and equally limited funds and technical competence to operate and maintain land disposal sites. The attainment of highly complex landfill design and construction as practiced in the developed world may not be realized immediately. The status of financial allocations that can be earmarked for solid waste management in many developing countries would require solid waste managers to attempt to modernize open dumping practices and gradually upgrade them. The waste managers should aim at modest improvements to their landfill operations and gradually move from open dumps to sustainable landfills in a phased manner.

The traditional model of a landfill as a permanent waste deposit in which decomposition processes are minimized is expected to give way to the concept of a controlled decomposition process managed as a large-scale bioreactor. This controlled bioreactor landfill is seen as being a flexible, cost effective, and sustainable approach to current waste disposal problems, particularly when combined with material recovery either before or after the biological treatment step. Indeed, it may no longer be necessary to view landfilling as a disposal system at all but rather to see it as a method for large-scale processing of waste to be combined with recovery and recycling processes. The concept of landfill mining and reclamation and related technology merits serious consideration. It may be relevant to consider the incorporation of the concept into landfill design so that the landfill waste can be readily accessible for mining a multi- disciplinary approach to landfill management. Involving such professional groups as geochemists, geotechnical engineers, civil engineers, environmental engineers and microbiologists will lead to a rapid development of the concept of landfill mining as a sustainable technology. Besides dumpsites there are many polluted sites all over the world that needs remediation and this rehabilitation needs to be done quickly in order not to destroy more of the scarce groundwater and surface water resources available. It is likely that land rehabilitation will be more common in the future all over the world and in particular necessary in countries that also in future will use waste dumping as a waste handling method.

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