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DISPOSAL OF SOLID WASTES BY SANITARY LANDFILLING LATEST PRACTICES IN THE UNITED STATES

The aim of this monograph is to place sanitary landfilling in a correct perspective by revealing the current standards, their effects on site preparation and operating procedures, and the cost of a faithfully executed operation. The overall intent is to supplement the excellent research and development work on the new concepts with a practical review of their full-scale applications.

Although the principles of sanitary landfilling have been well established for over 20 years, few exist today. To complicate matters further, the recent concerns with ecology, needs for stricter environmental and health controls, and demands for resource recovery now require even more exacting regulations. Paradoxically the new standards and attendant increased costs have further widened the gap between theoretical performances and actual accomplishments. The causes for this history of woeful implementations are (1) considerable published misinformation on alleged simplicity of operation, low costs, and lucrative reclamation of salvageable metals; (2) inferior planning with consequent inadequate butgeting; and (3) regression in quality of performance under fiscal pressures.

Any fully acceptable disposal system should be capable of (1) handling all the community's solid wastes; (2) meeting all the antipollution regulations and public health controls; (3) maximizing recovery of energy and resources; and (4) minimizing capital and operating costs. To meet these objectives, former performance guidelines for sanitary landfilling have been modified by requiring auxiliary systems for (1) milling of normal-sized refuse, (2) fragmentizing of oversized wastes, (3) control of leachates, (4) control and recovery of generated gases, and (5) recycling and energy recovery.

1. MILLING

The initial enthusiasm for fine preshredding of normalsized refuse before landfilling has waned considerably. Experience has shown that the system (1) still required the use of all of the basic principles of the conventional sanitary landfill, including a daily appli-

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cation of clean cover material; (2) was limited to disposal of normal-sized refuse; (3) presented more severe leachate problems and controls; (4) in no way enhanced the recovery of salvageables; and (5) increased the overall operating costs by the cost of fine shredding — \$2.76 to \$5.51 per metric ton. Although the Research and Development project in Madison, Wisconsin, was quickly followed by several installations, none have adhered to the established guidelines or have produced the claimed benefits or economies. Advance detailed engineering studies of these and other local factors are essential towards achieving a sucessful milling process for any given community.

2. FRAGMENTIZING

About 8 to 18 percent, by weight, of community refuse consists of oversized wastes (home and office furniture and fixtures, waste lumber, tires, tree trunks, branches and stumps, and the like). Generally these wastes are collected and delivered separately. Former burial practices at the landfill created problems of more rapid depletion of available space, rodent harborage, gas pockets, fire hazards, and unequal settlements. This was partially corrected by the current practice of on-site crushing and flattening with heavy rolling equipment, and burial in successive shallow layers. This practice, however, is costly and negates any retrieval of valuable metallics.

The latest solution calls for a large-sized, high-powered shredder, at a transfer station or at the landfill. The fragmentized material, after metallics recovery via magnetic separation, is of relatively uniform size and readily compactable. Capital costs will range from \$11,000 to \$33,000 per metric ton per hour of oversized wastes, and operating costs (mostly power and maintenance) from \$5.50 to \$8.80 per metric ton fragmentized. The revenue from salvaged metallics, about 25 to 40 percent of OBW at \$11.00 per metric ton, will approximate \$2.75 to \$3.41 per metric ton of the oversized wastes. The net added cost, averaging less than \$0.55 per metric ton of total refuse disposed of appears to be well justified by the end results — more sanitary and less hazardous disposal.

3. LEACHATES

Hydrogeological studies show that, except for the southwest region, about two-thirds of the total U.S. area is susceptible to the degradation of water resources by landfill leachates. Interaction of the migrating surface and groundwaters and the deposited solid wastes generates a contaminant whose composition and amount are mostly affected by types of refuse, climate, extent and character of the migrating waters, and age of the fill. Although generally categorized as strong sewage, it can range up to a BOD (Biochemical Oxygen Demand) of 15,000 ppm, a COD of 50,000 ppm, and a pH of 4.00 to 8.50.

Corrective controls include (1) minimizing entry of surface and groundwaters by interception, diversion, and use of a suitable top surface impervious membrane; (2) collection of leachate by means of watertight bottom membranes; and (3) treatment of leachate before final discharge into adjoining streams or ponds. Item (1) is effected through grading, channeling, and use of a natural clay earth cover, an asphaltic layer, or a plastic membrane. Item (2) is effected by laying a bottom membrane of impervious asphaltic concrete or a thin plastic sheet on a properly graded blanket of sandy soil and then covered by a protective 0.6 meter deep sand blanket. Item (3) can be a relatively small-sized and inexpensive flexible treatment process combining physical and chemical basic processes with more sophisticated biological processes or natural lagooning. Item (1) is already part of the established guidelines. Items (2) and (3) with respective costs of about $6.00 per square meter and $200,000 are new elements essential to maintaining public health.

4. GASES

The biochemical decomposition of solid wastes generates over 90 percent of CO_2 and methane gases with traces of hydrogen sulphide, carbon monoxide, and others. Carbon monoxide in form of carbonic acid with its dissolving action on soil minerals can adversely affect water resources. Methane can become a major explosive and fire hazard. If properly collected and used it can become a source of heat energy. The highly odorous hydrogen sulphide can be a major water pollutant and general nuisance.

Substantial research has been made on gas generation and diffusion. Practical applications for their control and use have been mostly improvised. Further studies and applications are required to establish whether their control and/or recovery should become an essential requirement for sanitary landfilling.

5. RESOURCE RECOVERY

The retrieval of salable items from refuse ranges from the simple but costly manual sorting to the complex mechanical methods. It can be practiced alone or with most types of disposal systems. Recovery of heat energy, however, is limited to the thermal disposal systems. To date recycling has had limited success except when heavily subsidized financially or by voluntary labor. Inclusion of unsubsidized recycling systems with sanitary landfilling is more burdensome than profitable. On the other hand, the recovery of excess heat and metallics as intimate parts of the thermal systems is gaining more momentum.

6. COSTS

A cost analysis (1975 Cost Index) for all the elements essential to compliance with the U. S. EPA (Environmental Protection Administration) standards for sanitary landfilling follows. Since such costs will vary with local conditions — a probable range of 80 to 120 percent of a median situation, the following typical conditions were postulated.

1. For meaningful comparison with acceptable thermal systems the assumed „useful life" is 25 years.
2. Average population (residential, plus commerical and industrial equivalents) — 100,000.
3. Total refuse delivery in 25 years at an average of 2.72 kilograms per capita per day = 2,500 000 metric tons.
4. Required gross land area for a compacted depth of refuse of 6.1 meter, including one 15 cm and one 60 cm earth cover = 134 hectares.
5. Character of landfill site — rolling, partially wooded land, with adjoining waters, a water table about 1.5 meter from ground surface. Subsurface varying from sandy through clayey, gravelly, and rocky soil.
6. Distance of site to center of collection area — 16 kilometers one way.

7. CAPITAL COSTS

1. Land acquisition:	
a) Purchase price at $2,470 per hectare plus interest at 7 percent for 25 years —	$ 620,000
b) Future sale of completed fill at $9,877 per hectare —	$ 1,320,000
c) Anticipated gain from resale —	$ 700,000
2. Site preparation:	
a) Cleaning, grubbing, grading, and drainage at $555 per hectare —	$ 75,000
b) Access roads, diking, and fencing, L.S. —	130,000
c) Procurement of earth cover at $0.78 per cubic meter —	800,000
d) Truck scale, headquarters and maintenance shed, utilities, L.S. —	60,000
e) Leachate control, bottom membrane at $6.0 per square meter plus treatment plant —	8,100,000
f) Fragmentizer for oversized wastes —	135,000
Total for Site Preparation	$ 9,500,000
3. Equipment at landfill:	
a) Two 18-ton bulldozers	$ 50,000
b) One 11.5 cubic meter scraper	35,000
c) One 11.5 cubic meter dump truck	20,000
d) One flusher	35,000
e) Miscellaneous tools, portable pumps, etc.	10,000
Total	$ 200,000
This equipment with its 12–1/2-year useful life will require one additional replacement for a total purchase cost in 25 years of —	$ 400,000

4. Haulage equipment: Direct haulage with collection trucks will be more economical for the assumed 16-km distance than a transfer station-trailer system. It will, however, require an increase of about 25 percent in the fleet, i.e., nine trucks at $22,250 for a total of —	$	200,000
Their 12–1/2-year useful life will require one replacement for a total purchase cost in 25 years of —	$	400,000
Total Capital Costs		$10,300,000

8. OPERATING COSTS

1. Landfill costs: Based on average operating costs per metric ton at six sound landfill operations maintaining dependable cost records.		
a) Operating labor, including vacations and sick leave —	$	0.95
b) Supervision, administration, pensions, and fringe benefits —	$	0.31
c) Supplies, utilities, and maintenance of equipment and landfill —	$	0.35
d) Added operating costs (labor, power, supplies) of fragmentizer and leachate treatment —	$	0.45
Total for 25 years —	$	2.06
2. Haulage costs: Total for the 45 collection trucks at two round trips per day for 300 days per year and 25 years.		
a) Labor, including supervision and fringe benefits, at $6.50 per hour —	$	4,400 000
b) Fuel and maintenance at $1.10 per round trip —	$	750 000
c) Unit cost ($5,150 000—2,500 000 metric tons —	$	2.06
d) Total unit operating cost per metric ton of refuse hauled and disposed of over the 25 years —	$	4.12

CONCLUSIONS

1. To be fully acceptable by health authorities, sanitary landfilling must control leachates, prefragmentize oversized wastes, and use daily cover for all refuse.
2. Capital costs of leachate membrane and treatment plant will be about $3.86 per total (lifetime) metric ton of wastes disposed of. This high cost may, however, permit the use of nearer and less costly sites.
3. Haulage costs, excluding amortization, approximate $0.35 per metric ton kilometer and will generally double the cost of operating a true sanitary landfill. The total cost for a U.S. median condition will approximate $4.13 per metric ton disposed of.
4. Recycling of salvageables and recovery of heat energy in conjunction with sanitary landfillings is impractical and uneconomical. Conversely, salvaging of metallics

and heat energy in conjunction with the thermal processes are viable and can produce cost-offsetting revenues of $3.30 to $4.41 per metric ton of refuse destroyed.

5. Disposal by the thermal process promptly destroys most pathogens. All sanitary landfilling methods retain potential health hazards for many years.

UNIESZKODLIWIANIE STAŁYCH ODPADÓW W SKŁADOWISKACH UPORZĄDKOWANYCH OSTATNIE OSIĄGNIĘCIA AMERYKAŃSKIE

Sformułowane przed laty zasady budowy i eksploatacji wysypisk uporządkowanych są nadal rozwijane i modyfikowane. Rozwój ten idzie w kierunku sprostania coraz surowszym nakazom prawnym oraz takiego obniżenia kosztów, by metoda składowania mogła być w dalszym ciągu konkurencyjna w stosunku do innych metod unieszkodliwiania odpadów.

W artykule szczególną uwagę zwrócono na rozdrabnianie, badanie ilości i składu przecieków z wysypisk, wydzielanie gazów.

Artykuł uzupełnia analiza kosztów według wskaźnika cen z roku 1975.

MÜLLBEWACHUNG UND -TECHNIK IN SANIERTEN DEPONIEN (DIE NEUESTEN ERFOLGE IN DEN VEREINGTEN STAATEN)

Die vor Jahren entwickelte Technik der Beseitigung von Abfällen durch Deponie sowie jene für den zweckmäßigen Betrieb und Überwachung von Deponien werden weiterentwickelt und modifiziert. Diese Weiterentwicklung ist darauf gezielt, den hohen Grundforderungen des Umweltschutzes zu entsprechen und gleichzeitig die Betriebs- und Überwachungskosten herabzusetzen, damit die Deponientechnik im Konkurrenzkampf mit anderen Beseitigungsmethoden nicht ausgeschieden wird.

Andere Forderungen wie Deponiedichtung und -drainage sowie Sickerwasser- und Gaskonzentrationsanalyse werden unterstrichen.

Der Aufsatz ist mit einer Kostenanalyse (für das Jahr 1975) bereichert.

ОБЕЗВРЕЖИВАНИЕ ТВЕРДЫХ ОТБРОСОВ НА УПОРЯДОЧЕННЫХ ОТВАЛАХ

Сформулированные много лет тому назад принципы строения и эксплуатации упорядоченных отвалов мусора непрерывно подвергаются дальнейшему развитию и модификации. Развитие их устремлено в таком направлении, чтобы они смогли удовлетворять все более строгим требованиям и чтобы возможным было такое снижение издержек, которое обеспечивало бы методу складирования конкурентоспособность по отношению к другим методам обезвреживания отбросов.

Особое внимание уделено размельчению, исследованию количества и состава протечки из отвалов и выделению газов. Статья дополнена анализом издержек по уровню цен 1975 г.