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INTERNATIONAL REPORT

STABILIZATION OF SOLID WASTE THROUGH LEACHATE RECYCLING

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1. Landfill stabilization

One characteristic which landfills have in common is the long stabilization times they require. Stabilization implies that conditions within the fill have achieved a state of relative physical, biological and chemical immutability (Zison 1974). Some investigators have claimed that stabilization requires as little as four years (APWA, 1966), while other authorities hold the view that stabilization may require considerably longer. There have been instances, for example, where wastes in landfills over fifty years old have yielded readable newspapers (Zison 1974). The concept of stabilization has been studied more in depth (Stanforth *et al.* 1979; Todd & Ham 1982; Kelly 1987; Pohland *et al.* 1983; Pohland *et al.* 1987). The causes of the extended periods of time required for the organic fraction of the waste to stabilize are not well known. However, there are several possibilities, including:

1. Excessively high carbon to nitrogen ratios in the range 120:1 may inhibit bacterial activity within the fills.
2. Anaerobic decomposition is inherently slower and less complete than aerobic. (Stabilization in modern, engineered landfills is almost exclusively an anaerobic process).
3. Substances in the initial waste or products of the stabilization process may be toxic to decomposition. Biochemical feedback mechanisms may be responsible for a decreased rate of waste decomposition due to the resultant inhibition of enzyme synthesis or transport systems.
4. Certain components of waste, such as cellulose may be slow to decompose due to their molecular structure.
5. As decomposition slowly progresses, changes in pH may inhibit the metabolism or reproduction of microorganisms. Methane forming anaerobics, for example, are known to be very sensitive to pH changes.

2. Laboratory experimentation procedure

The research work undertaken involved setting up in the laboratory four simulated landfill lysimeters. Although the four lysimeters, each containing 30 kg of waste, were the same in physical construction, they were loaded and operated differently. Details of the refuse loaded into each lysimeter and the mode of operation of each are summarized in Table 1, while a typical lysimeter is shown in Fig. 1.

Small scale laboratory experiments were carried out because they permitted a wider range of parameters to be studied than would have been possible in actual landfills. It is,

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TABLE 1

Details of refuse and mode of operation of simulated lysimeters

Lysimeter no.	Type of refuse	Mode of operation
Lysimeter 1	fresh crude domestic[a]	free draining leachate[c]
Lysimeter 2	fresh crude domestic	saturated with leachate[d]
Lysimeter 3	fresh shredded domestic	free draining leachate
Lysimeter 4	aged domestic[b]	free draining leachate

[a] refuse collected from a local waste transfer station.

[b] refuse collected from a landfill estimated to be 10 years old, as evidenced by the dates of newspapers obtained.

[c] initially 100 litres of distilled water added, thereafter two litres per week added.

[d] completely saturated as evidenced by the water level in the tubes.

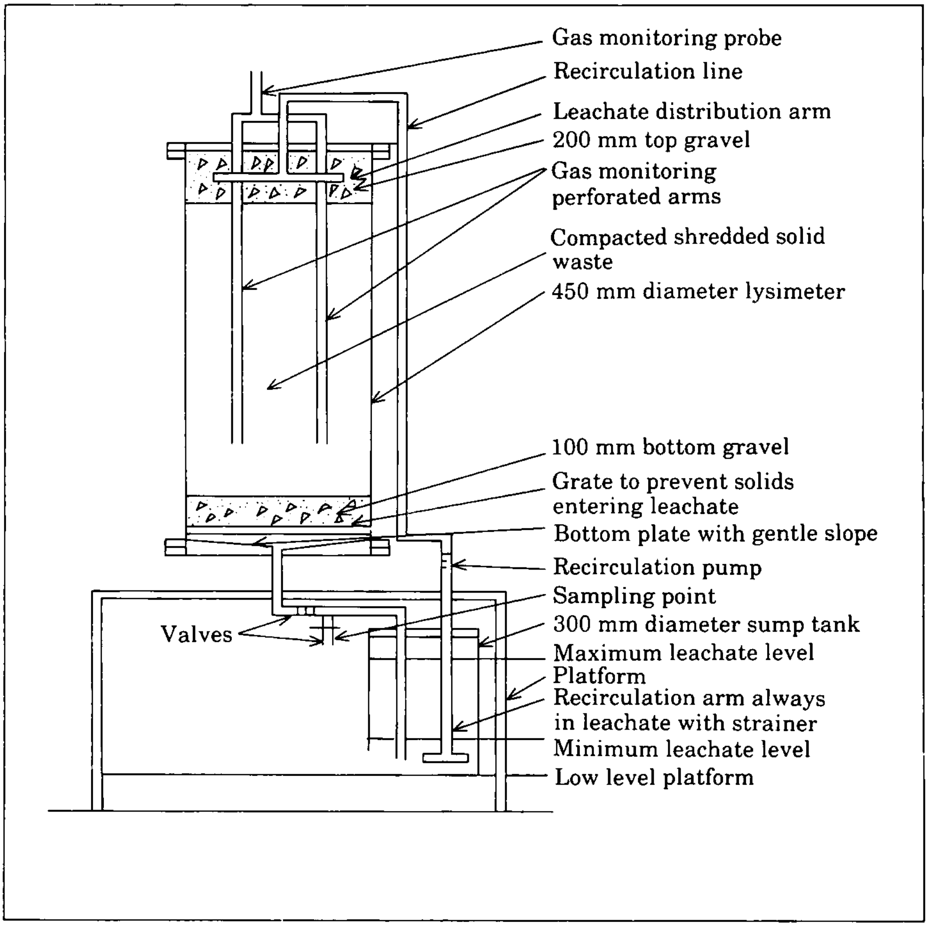

Fig. 1. Typical lysimeter

TABLE 2
Composition of the test refuse

Constituent	Weight (kg) at 61% moisture content	Percentage weight
Paper	11.500	37.58
Plastics	3.500	11.44
Wood	0.395	1.29
Metal	0.205	0.67
Rags	2.250	7.35
Minerals (Fines)	12.750	41.67
Total	30.600	100.00

TABLE 3
Characteristics of the test refuse during loading

	Lysimeter number			
	1	2	3	4
Moisture content %	61	61	44	85
Density at placement kg/cubic metre	383	418	306	550
Total Volatile Solids as % dry raw sample	86	86	87	54
Total Volatile Solids as % dry crushed sample	88	88	88	90

however, pointed out that decisions based on such studies alone, cannot replace judgement based on full scale investigations. These results, however, give a useful basis upon which to launch pilot and full scale investigations.

Tables 2 and 3 further provide details of the composition of the refuse and the characteristics of the test refuse respectively at time of loading.

Leachate recirculation was achieved automatically using a liquid level indicator in the sump tank. Falls in the liquid level triggered a peristaltic pump. The rate was not regulated but depended on the rate of infiltration of leachate through the solid wastes (i.e. higher in fresh refuse and much slower in aged refuse). Leachate was periodically collected and analysed to determine its chemical composition using APHA standard methods (1985). These data were then compared with similar information collected earlier to establish trends in constituent concentrations. According to Tittlebaum (1979), (1982); and Pohland *et al.* (1983), the four parameters used to evaluate the effects of leachate recirculation on landfill stabilization were Total Volatile Acids (TVA), Biochemical Oxygen Demand (5 days) (BOD_5), Chemical Oxygen Demand (COD), and Total Organic Carbon (TOC). Analyses of these parameters over 400 days was performed and the results are presented in Figs 2, 3, 4 and 5.

3. Results and discussions

When addressing the concept of landfill stabilization and hence leachate quality, the issue of organic carbon content stabilization is important. This was investigated by examining COD, TOC, TVA, and BOD_5 data simultaneously. For example, the concentration of TVA is an important parameter because of the stage and degree of

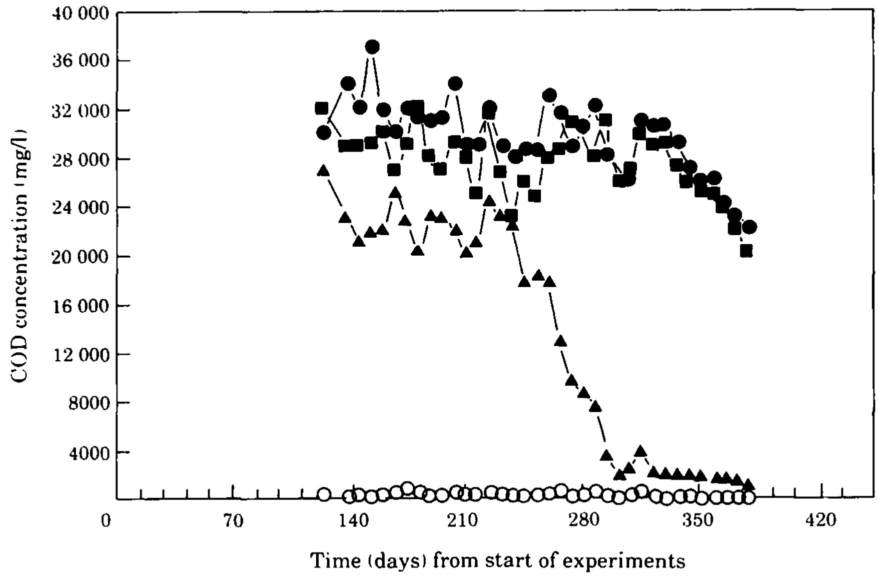

Fig. 2. COD variation during the study period. (●) lysimeter 1, (■) lysimeter 2, (▲) lysimeter 3, (○) lysimeter 4.

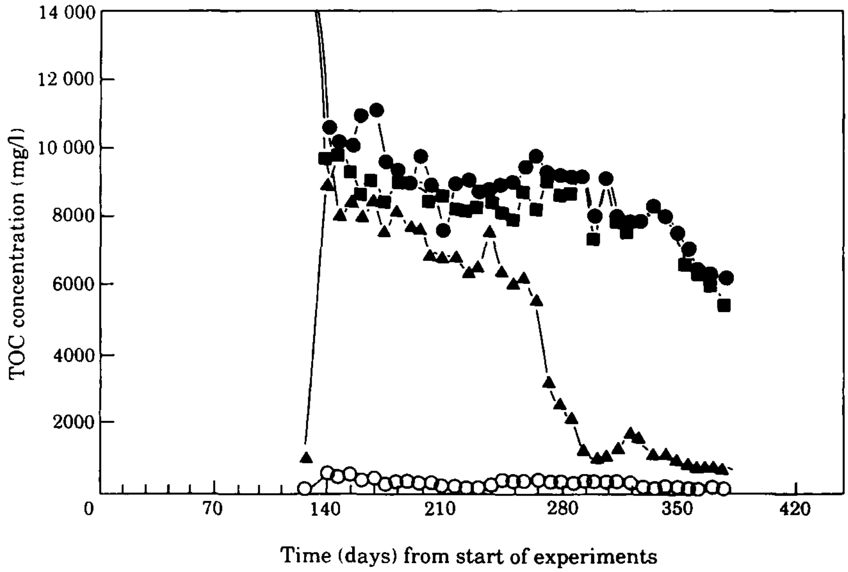

Fig. 3. TOC variation during the study period. Key as Fig. 2.

stability of the anaerobic process. Fig. 4 shows the TVA concentration in leachate from lysimeters 1, 2 and 3. In leachate from lysimeter 4, the TVA steadily decreased from about 2000 mg/l down to about 240 mg/l at day 378, while those for lysimeters 1 and 2 started off at about 18 000 mg/l with slight oscillations until about day 264 when they started to steadily fall to about 13 000 mg/l on day 378. TVA for leachate from lysimeter 3 steadily fell from about 14 000 mg/l on day 224 to 300 mg/l on day 378. The changes

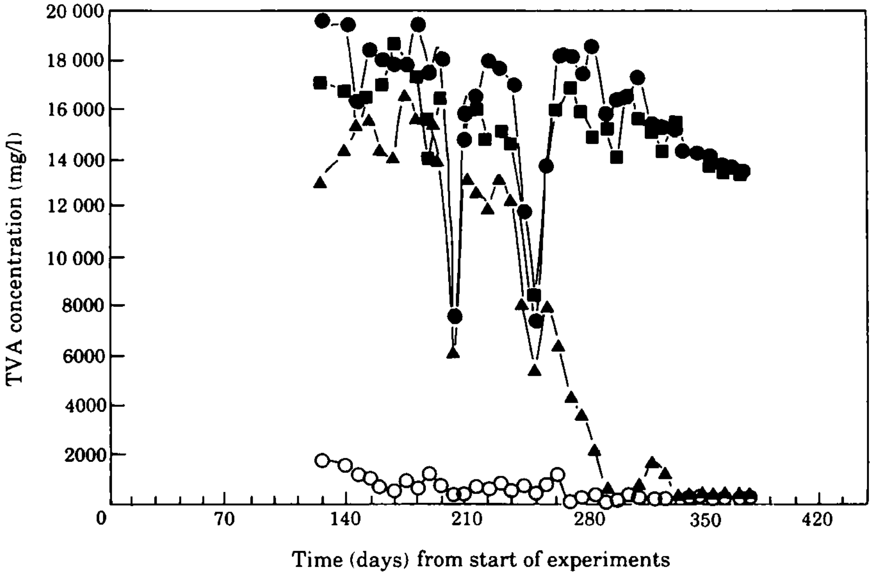

Fig. 4. TVA variation during the study period. Key as Fig. 2.

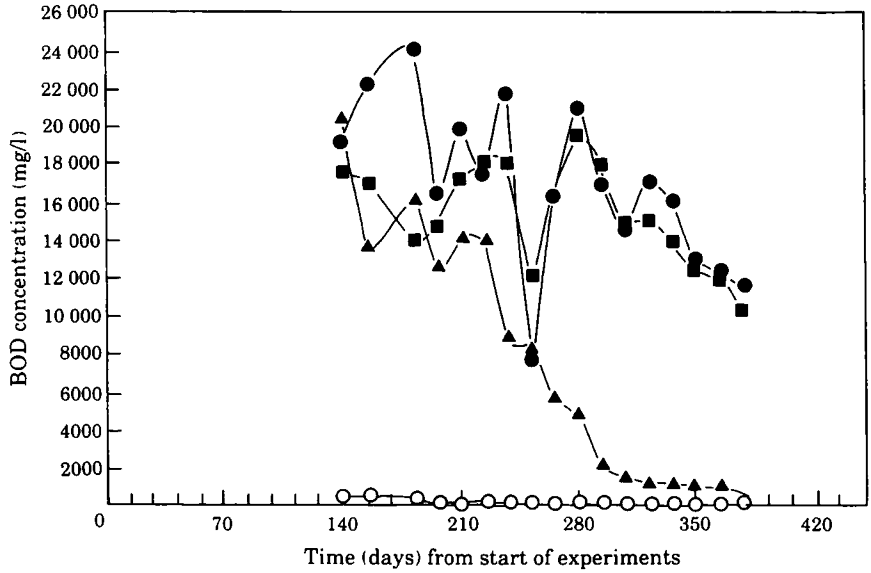

Fig. 5. BOD variation during the study period. Key as Fig. 2.

from high levels of TVA to considerably lower concentrations are indicative of the removal pattern of the readily available organic pollutants from the refuse and leachate with an eventual attack on materials that are more resistant to biological stabilization (Tittlebaum 1979, 1982; Pescod *et al.* 1982; Pohland *et al.* 1983).

When investigating the removal of organic pollutants, it is also necessary to examine data relating to COD, TOC and BOD_5. Figs 2, 3 and 5 give variations in leachate levels for those parameters throughout the study period. The levels of these parameters in

TABLE 4
Changes in the BOD_5/COD ratios during study period

Day	Lysimeter number			
	1	2	3	4
140	0.56	0.60	0.89	0.55
154	0.60	0.59	0.62	0.54
182	0.77	0.43	0.80	0.53
196	0.53	0.54	0.54	0.13
210	0.68	0.61	0.70	0.07
224	0.54	0.58	0.57	0.39
238	0.77	0.77	0.39	0.11
252	0.27	0.48	0.47	0.10
266	0.51	0.57	0.44	0.03
280	0.69	0.66	0.56	0.10
294	0.60	0.58	0.61	0.06
308	0.56	0.54	0.62	0.03
322	0.54	0.52	0.55	0.11
336	0.52	0.51	0.56	0.25
350	0.50	0.49	0.52	0.25
364	0.51	0.50	0.55	0.33
378	0.52	0.51	0.54	0.50

these figures follow to a large extent the same removal or reduction trends as those for TVA. BOD_5 readings are somewhat erratic due to similar problems experienced by other researchers in the measurement of BOD_5 in leachates (Pohland & Harper 1986; Rees 1982).

Residual concentrations of TVA continued to exist in leachate from lysimeters 3 and 4 even after the concentrations were reduced to relatively low levels. This may partially be explained by the fact that more resistant materials normally present in refuse were still being attacked after the stabilization of the readily available organics. In order to study in greater detail the proportion of biodegradable organic carbon in the leachate, it was considered meaningful to study the ratio BOD_5/COD as opposed to their absolute values (Table 4). Computed values of this ratio for leachate for the four lysimeters are presented in Table 4. It is documented in the literature (Pohland & Harper 1986) that BOD_5 ratio between 0.02–0.13 implies a leachate with a low biodegradability in the final maturation phase, whilst one between 0.4–0.8 implies a highly biodegradable leachate. (The degree of ease increases with BOD_5/COD ratio). These authors further point out that in the transition phase, this ratio lies in the range of 0.17–0.87, indicating increasing biodegradability of organics due to solubilization, and that in the methane fermentation phase, this ratio is between 0.17–0.64 showing a decreasing biodegradability due to methane.

Another area of interest in evaluating carbon content reduction is the TOC data itself. TOC should, in theory, give an indication of the amount of organic substrate in the leachate. COD and BOD_5 data for leachate from lysimeters 1, 2 and 3 were always higher than TOC. However, TOC data for leachate from lysimeter 4 obtained during the last 140 days of the research were higher than both COD and BOD_5. Such an observation is not common, and a possible explanation of this could be the fact that this lysimeter reached the final maturation stage much earlier during the study period and was fairly dormant for most of the second half. The accumulation of carbon dioxide in the lysimeter thus caused the high TOC. This hypothesis is further supported by deductions based on BOD_5/COD ratios.

The third area of general interest concerns the actual concentrations, and subsequent reductions of COD, TOC and BOD_5 in leachate from all the lysimeters. These parameters in leachate from lysimeters 1 and 2 were higher than those in leachate from lysimeters 3 and 4 over the study period. This may be explained by one of two reasons. First, lysimeter 3 contained shredded refuse which must have provided increased surface area for oxidation by biological action, while lysimeter 4 , because of the age of the refuse and the subsequent density, may also have simulated similar conditions as those of lysimeter 3. Further, lysimeter 4 originally had low levels of these contaminants and although they were fully reduced to concentrations below those in lysimeters 1 and 2, the actual percentage reductions are not different for those of leachate from lysimeters 1 and 2.

4. Conclusions

A comparison of the COD, TOC, TVA and BOD_5 in terms of percentage removal and stabilization of readily available organics in the refuse indicates that lysimeters 3 (fresh shredded domestic refuse) and 2 (fresh crude domestic refuse) performed relatively less satisfactorily compared to lysimeters 3 and 4. This reduction in performance appears to correspond to TVA reduction in the leachate.

References

American Public Works Association, (APWA) (1966). *Municipal Refuse Disposal.* Interstate Printers and Publishers, Danville, Illinois, U.S.A.

Kelly, H. G. (1987) Pilot testing for combined treatment of leachate from a domestic waste landfill site. *Journal of Water Pollution Control Federation*, **59**, 254–261.

Otieno, F. A. O. (1989) Impact of Recirculation on Landfill Leachate Quality. Ph.D Thesis, Dept. of Civil Engineering, University of Newcastle Upon Tyne, U.K.

Pescod, M. B. KilKenny, W. M., Evision, L. M., and Elliott, D. J. (1982) *Technical Review of Hazardous Liquid Waste Disposal: Choppington Waste Disposal Site.* Publication of the Department of Civil Engineering, University of Newcastle Upon Tyne, U.K.

Pohland, F. G., Dertien, J. T., and Ghosh, S. B. (1993) Leachate and Gas Quality Changes during Landfill Stabilization of Municipal Refuse. *Proceedings 3rd International Symposium on Anaerobic Digestion, August, Boston, U.S.A.*

Pohland, F. G. & Harper, S. R. (1986) Critical Review and Summary of Leachate and Gas Production from Landfills. PB 86–240181, USEPA, Atlanta, U.S.A.

Pohland, F. G., Schaffer, T. R., Ravi, S. & Cross, W. H. (1987) The Fate of Selected Organic Pollutants during Landfill Disposal Operations. AD–A180 117, USEPA, Atlanta, U.S.A.

Rees, J. F. (1982) Landfill management and leachate quality. *Proceedings Landfill Leachate Symposium, Harwell, U.K.*

APHA. (1985) *Standard Methods for the Examination of Water and Wastewaters.* 16th Edition, American Public Health Association, Washington, DC, U.S.A.

Stanforth, R., Ham, R., Anderson, M. & Stegmann, R. (1979) Development of a synthetic municipal landfill leachate. *Journal of Water Pollution Control Federation*, **51**, 1965–1975.

Suess, M. J. & Huismans, J. W., (Eds). *Management of Hazardous Waste.* WHO Regional Publication, European Series No. 14, WHO, Copenhagen, Denmark, 1983.

Tittlebaum, M. E. (1979) Investigation of Leachate Heavy Metal and Organic Carbon Content Stabilization. Ph.D Thesis, Dept. of Civil Engineering, University of Louisville, Kentucky, U.S.A.

Tittlebaum, M. E. (1982) Organic carbon content stabilization through landfill leachate recirculation. *Journal of Water Pollution Control Federation*, **54**, 423–433.

Todd, J. B. & Ham, R. K. (1992) Stabilization of solid waste in landfills. *ASCE, Journal of Environmental Engineering Division*, **108**, 1089–1100, 1982.

Zison, S. W. (1974) Effects of Metal Toxicants on Decomposition Phenomena in a Simulated Solid Waste Disposal System. Ph.D Thesis, Drexel University, Drexel, U.S.A.