

Annex WAS

TECHNICAL INFORMATION ON LEACHATE

According to R. Stegman (Institut für Stadtbauwesen, Technische Universität Braunschweig, Germany) leachate quality is to a high degree dependent upon the kind of processes that take place in a landfill. Aerobic processes take place on the surface of the fill as well as during a short period of time within the fill until the oxygen is consumed. By far the main degradation of the organics takes place under anaerobic conditions. Under these conditions the organics are broken down subsequently in different phases mainly into CH₄ and CO₂. In the acid phase high concentrations of organic acids, hydrogen and CO₂ are produced. Some of these products can be used directly by methane-forming bacteria to produce methane and in some cases water. In actual landfill the balance between acid- and hydrogen-, on one hand and methane-producing bacteria on the other takes some time to be reached. The generation rate of methane bacteria is about 10-20 times lower than the generation rate of the acid and hydrogen producers. In addition, high organic acid concentrations inhibit the methane bacteria, which results in highly organic polluted leachate over a long period of time.

Compared with sewage, leachate is an organically and inorganically highly pollution water. In the surveys carried out by Stegman in 15 sanitary landfill in Germany, high salt but relatively low heavy metal concentrations were detected. Some of the parameters were dependent upon the biological stage (acid or methane phase) in the landfill. Almost all parameters are influenced by the age of the landfill, although there is no indication of the influence of landfill height. The following table shows some figures on undiluted leachate of the investigated 15 landfills.

WAS-T-1 Mean and maximum concentrations of different leachate quality parameters representing the "acid" and "methane" phase (Ehrig, 1982)

Parameters	Acid Phase		Methane Phase	
	Mean	Maximum	Mean	Maximum
pH*	6.1	5.5	8.0	8.5
BOD ₅ /COD*	0.68	-	0.06	-
COD	22000	38100	3000	4340
BOD ₅	13000	30425	180	383
Fe	925	2120	15	29.3
Ca	1300	1130	80	534
Mg	600	1130	250	1.73
Mn	24	65.5	0.65	1.75
Zn	5.6	68.4	0.64	3.78
Sr	7.2	14.7	0.94	7.25
SO ₄	-	1745	-	884

Note: * without dimension; other parameter: [ppm]

Source: STEGMAN, R.; "The pollution potential of sanitary landfill". Proceedings of the Exeter Symposium. IAHS Publ. no. 139. July/1982.

Other parameters were not found to be dependent upon the stage of decomposition of the waste. These parameters are shown in the following table.

WAS-T-2 Mean, maximum and minimum concentrations of different leachate quality parameters where no dependency could be found (Ehrig, 1982)

	Mean	Minimum	Maximum
Spec. conductivity*	13986	2100	27150
NH ₄ -N	741	26.3	3075
NO ₃ -N	3.3	0.2	35.0
Organic Nitrogen	593	8.3	4245
Cl	2119	134	4953
K	1085	94	2420
Na	1343	70	3560
ges. P	5.7	0.5	30.2
Alkalinity**	6609	677	11575
As	0.126	0.007	1.56
Pb	0.087	0.008	1.02
Cd	0.0052	0.001	0.00629
Cr	0.275	0.029	1.57
Co	0.05	0.004	0.954
Cu	0.065	0.010	1.39
Ni	0.166	0.0183	2.05
Hg		0.0002	0.061
F		-	0.6
Phenol		0.022	75.0

* [$\mu\text{s cm}^{-1}$]; ** [ppm CaCO₃]; other parameter [ppm]

Source: STEGMAN, R.; "The pollution potential of sanitary landfill". Proceedings of the Exeter Symposium. IAHS Publ. no. 139. July/1982.

As for the quality of leachate produced in some landfills in Brazil, the following table presents some parameters values, important for the anaerobic stabilization, in several sanitary landfills in the city of São Paulo.

WAS-T-3 Comparison of physical and chemical parameters of the infiltrated liquids in sanitary landfills in São Paulo

Parameters	VILA ALBERTINA			ENGENHEIRO GOULART			RAPOSO TAVARES km 14.5			PEDREIRA CITY			GERAL	
	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Max.
BOD (Biochemical Oxygen Demand)	690	10,919	19,800	480	3,738	7,700	700 ^(b)	1,389 ^(b)	2,270	3,260 ^(b)	3,675	4,020	480	19,800
COD (Chemical Demand Oxygen)	4,380	18,110	28,000	966	5,836	12,500	6,080	6,671	7,640	6,500	7,163	8,100	966	28,000
pH	5.9	6.6 ^(c)	7.3	-	-	-	8.4	8.5 ^(c)	8.7	7.2	7.2 ^(c)	7.3	5.9	8.7
Total Solid	9,850	14,431	19,800	3,100	3,155	3,200	15,900	18,709	21,400	11,800	16,575	26,300	3,100	26,300
Fixed Solid	5,020	7,825	12,600	270	1,646	3,270	11,500	12,967	15,100	7,500	8,815	10,900	270	15,100
Volatile Solid	3,800	6,740	10,400	248	1,715	3,505	3,680	5,769	9,700	4,100	7,793	15,400	248	15,400
Total Nitrogen	440	709	1,050	15	127	275	2,430	2,729	3,140	940	1,003	1,100	15	3,140
Phosphorus	3.70	7.40	14.30	-	-	-	-	-	-	-	-	-	3.70	14.30

Source: Schalch, V.; "Production and Characteristics of Leachate in Decomposition Process in the Domestic Solid Waste"; Master's Thesis; USP, March/1984.

Note: (a) units in mg/l, except pH
 (b) probable presence of inhibitors
 (c) average value

As another example of leachate characteristics, we hereinafter describe an experiment carried out by Valdir Schalch (Faculty of Engineering of São Carlos – University of São Paulo) for the elaboration of a thesis for the achievement of the title of Master in Hydraulics and Sanitation. The thesis is named “Production and Characteristics of Leachate in Decomposition Process in the Domestic Solid Waste” (March/1984).

In this experiment, parameters indicating the anaerobic process stabilization were utilized for evaluation. The measurements were carried out based on the “Standard Methods for the Examination of Water and Wastewater” (American Public Health Association) and in the Technical Standard NT-07-CETESB (Environmental Sanitation Technology Company – State of São Paulo).

Characteristics of the experiment:

- Start of the experiment: May 12th/1983
- End of the experiment: Dec 18th/1983
- Period of the experiment: 7 months
- Organic matter contents of the sample: 60% (in weight)
- Humidity contents of the sample: 50% (in weight)
- Quantity of the sample: 12 kg
- Quantity of leachate produced each 20 days, approximately: 90 ml
- Quantity of leachate necessary for each group of analysis and/or tests: 75 ml
- Total leachate produced during the experiment: 720 ml
- No addition of water. Production of concentrated leachate

WAS-T-4 Results of the Samples Analysis

Parameters	1983							
	Jun/15	Jun/29	Jul/19	Aug/12	Sept/2	Oct/8	Nov/5	Dez/18
Total Nitrogen (mg/l)	1,016.0	812.0	554.40	502.10	430.30	401.10	393.40	379.88
Phosphorus (mg/l)	167.0	102.75	98.10	92.30	89.12	81.40	77.10	74.35
Chemical Oxygen Demand - COD (mg/l)	35,250.0	27,888.0	15,314.0	13,215.0	10,190.0	8,319.0	7,100.0	6,972.0
Biochemical Oxygen Demand - BOD (mg/l)	26,150.0	18,501.53	6,220.24	4,820.10	2,980.15	2,100.10	890.18	291.67
Organic Matter (%)	61.98	59.40	49.27	48.03	44.92	40.12	37.27	35.48
Hydrogen Potential (pH)	6.43	7.10	8.65	8.80	8.95	9.10	9.18	9.29
Room Temperature (°C)	24	23	20	17	20	22	24	26
Sample Temperature (°C)	21	21	19	16	19	20	22	23
Humidity (%)	92.50	97.0	97.0	97.0	97.0	97.0	98.0	98.0

Source: Schalch, V.; “Production and Characteristics of Leachate in Decomposition Process in the Domestic Solid Waste”, Master’s Thesis, USP, March/1984.

Another experiment by Waquil and Freitas (“The Problem of Leachate Treatment in Sanitary Landfill”, Nov/1983) was carried out utilizing MSW from the city of Porto Alegre, Rio Grande do Sul State. The penetration of rainfall was not allowed, thus the amount of water to feed the experimental landfill was calculated based in the average annual rainfall of Porto Alegre (1,200 mm). The operation of the landfill was established in periods of 48 h. Therefore 6 liters of water used to be added at the end of the period before which 5 liters of gross leachate used to be withdrawn for laboratory analysis. The following table presents the results of this experiment in comparison with the parameters of other actual and experimental landfills in several places.

Sources	Unit	EXPERIMENTAL LANDFILLS				ACTUAL LANDFILLS			
		WAQUIL and FREITAS (1)	FUNGAROLI and STEINER (2)	QASIN BURCHINAL (4)	QASIN BURCHINAL (5)	SALVATO (6)	SALVATO (7)	JOHASEN and CARLSON (8)	CHIAN and DE WALLE (9)
Parameters									
pH		5.4-5.6	4.0-7.5	5.3-6.3	5.88	5.6	5.9	5.9	5.59
Alkalinity	mg/l CaCO ₃	2000-3200	-	5000-10630	10000-20850	8100	1710	39	284
Acidity	mg/l CaCO ₃	1000-2400	-	300-1800	1000-3510	-	-	-	-
BOD ₅	mg O ₂ /l	8000-15000	-	8000-14750	25000-33360	32400	7050	5250*	9960
COD	mg O ₂ /l	8500-17500	20000-22000	-	-	-	7130	9425	16580
Total - N	mg N/l	263-518	30-500	500	1500-2500	-	-	250	-
Organic - N	mg N/l	57-97	-	60-288	550-1416	550	152	23	78.5
Ammoniacal - N	mg N/l	166-432	-	70-473	750-1106	845	141	227	347.4
Chloride	mg Cl/l	500-800	50-2000	200-951	1500-2310	2240	-	370	474
Sulphate	mg SO ₄ /l	300-950	40-450	60-615	300-768	630	1220	100	77
Fe	mg Fe/l	60-66	10-1600	50-175	550-860	305	336	234	-
Zn	mg Zn/l	8.4-8.8	-	-	-	-	-	0.65	-
Pb	mg Pb/l	0.03-0.08	-	-	-	-	-	0.01	-
Cu	mg Cu/l	0.025-0.03	0.5-9.90	-	-	-	-	0.022	-
TSS	mg/l	1120-2855	-	-	-	-	-	466	192
TDS	mg/l	10150-11660	27000	-	-	-	9190	-	-
TS	mg/l	11270-14515	1000-400000	40000-60000	40000-60000	-	-	4160	7930

* Total BOD

- (1) WAQUIL, D.D.; FREITAS, A.R. "The Problem of Leachate Treatment in Sanitary Landfill". 12th Brazilian Congress of Environmental and Sanitary Engineering. Camboriú, Nov/1983.
- (2) FUNGAROLI, A.A.; STEINER, R.L. "Laboratory Study of the Behavior of Sanitary Landfill". Journal of Water Pollution Control Federation. Washington, 43 (2):252-67. Feb/1971.
- (3) QASIN, S.R.; BURCHINAL, J.C. "Leaching from Simulated Landfills". Journal of Water Pollution Control Federation. Washington, 42 (3):371-9, Mar/1970.
- (4) QASIN, S.R.; BURCHINAL, J.C. "Leaching from Simulated Landfills". Journal of Water Pollution Control Federation. Washington, 42 (3):371-9, Mar/1970.
- (5) SALVATO, J.A.; WILKIE, W.G.; MEAD, B.E. "Sanitary Landfill - leaching prevention and control". Journal of Water Pollution Control Federation. Washington, 43 (10):2084-100, Oct/1971.
- (6) SALVATO, J.A.; WILKIE, W.G.; MEAD, B.E. "Sanitary Landfill - leaching prevention and control". Journal of Water Pollution Control Federation. Washington, 43 (10):2084-100, Oct/1971.
- (7) JOHANSEN, O.J.; CARLSON, D.A. "Characterization of Sanitary Landfill Leachates". Water Research. 10:1129-34, Jun/1976.
- (8) CHIAN, E.S.K.; DE WALLE, F.B. "Sanitary Landfill Leachates and Their Treatment". Journal of the Environmental Engineering Division, New York, 102 (2):411-31, Apr/1976.

The following data on leachate refers to an actual Sanitary Landfill located in Caxias do Sul (RS). The leachate was collected from the cells C3 (already closed) and C4 (in operation at the time). The total amount of municipal SW in the C3 was 127,500 ton, and in the C4 92,000 ton (until July/1996). The hydro-geological characteristics of the landfill location and the climatic conditions of the region lead to a production of leachate much higher than that obtained through a conventional hydric balance. The percentage of organic matter in the municipal SW of Caxias do Sul is around 53.4%.

WAS-T-6 **Variation of Physical-Chemical Parameters of Leachate from the Landfill Cells C3 and C4 (January to June/1996)**

Parameters	Unit	Cell - C3		Cell - C4	
		Minimum	Maximum	Minimum	Maximum
pH		6.05	7.51	7.30	7.84
Alkalinity	mg CaCO ₃ /l	225	6,137	4,412	7,309
Volatile Total Solids	mg/l	257	1,322	1,238	2,410
Total Suspended Solids	mg/l	58	140	226	633
Total Dissolved Solids	mg/l	402	6,794	5,296	8,893
COD	mg O ₂ /l	90	2,000	1,672	2,500
Total Nitrogen	mg N/l	16.80	1,414	599	1,279
Ammoniac Nitrogen	mg N/l	14	1,080	308	1,192
Total Phosphate	mg PO ₄ /l	0.057	2,312	0.960	4,107
Chlorides	mg/l	275	1,949	1,474	2,324
Aluminum	mg/l	0.081	3,900	0.218	4,140
Barium	mg/l	0.073	13,222	0.112	5,482
Cadmium	mg/l	-	0.033	0.070	0.055
Chromium	mg/l	0.005	0.056	-	0.048
Copper	mg/l	0.008	0.190	0.025	0.128
Iron	mg/l	4.504	9.911	5.860	10.563
Nickel	mg/l	-	0.333	0.063	0.404
Lead	mg/l	0.021	0.700	0.106	0.809
Zinc	mg/l	0.040	0.350	0.081	0.725
Mercury	mg/l	-	-	-	-

Source: ARRUDA, A.C.S.; TEIXEIRA, C.E.; MANDELLI, S.M.De C.; PESSIN, N. (Professors of the Chemical Engineering Dept. of the Caxias do Sul University); SILVA, A.R. (Pos-graduation student of the Engineering School of São Carlos – University of São Paulo, Collaborator of the Solid Waste Group of the University of Caxias do Sul). "Leachate Treatment System Installed in the São Giacomo Landfill in Caxias do Sul – RS". **International Symposium of Environmental Quality.**