Municipal Waste Landfills

There are approximately 340 facilities in Washington under SIC code 4953 Refuse Systems (Ecology, 1/20/98). Besides landfills this could include incinerators and waste treatment plants.

Research data for municipal waste landfills is mostly oriented around methane generation rates and biology. There has been source testing done to evaluate what other compounds can be emitted from landfills. EPA, when developing the background document for the 40 CFR 60, Subpart WWW, reviewed the available data and evaluated the available emission models. Based on the source test data, EPA selected 12 organic compounds that showed up in essentially all the landfills for which data was reported. Of the chemicals reported and included in EPA's list, vinyl chloride is the most problematic. Vinyl chloride is not only present in the solid waste; it is also a byproduct of the biodegradation of other chlorinated compounds.

Methods of Determining Emissions

The emission controls that are available for use on landfill gas emissions are elevated burners ("tiki torches"), ground burners, various regenerative incinerators, conversion to methanol and hydrogen, internal combustion engines, gas turbines, and cleaning to pipeline-quality gas for sale.

All of these control methods result in a reduction of methane and other toxic and non-toxic hydrocarbons that are emitted in the landfill gases. All of them require that the landfill gases be collected and piped to one or more centralized control devices. At this time, no effective biological control methods have yet been devised.

The conversion of landfill gas from methane to carbon dioxide is encouraged by the international global warming accords and the EPA. Carbon dioxide is a much less potent greenhouse gas than methane. EPA's global warming initiative has been actively encouraging the installation of energy recovery systems at landfills which generate enough gas to support such systems.

A major concern with landfill emissions is the methane generation rate. Methane and carbon dioxide generated by anaerobic decomposition of wastes is the major means for non-methane organic compounds (NMOCs) to leave the landfill. This rate is dependent on the level of moisture in the landfill and requires a fully anaerobic environment. The bacteria that co-metabolize the various chlorinated compounds in the waste are often obligate anaerobes also. Early emissions of many chemicals from the landfill are dominated by volatilization of the chemical from the waste. Later, some of these chemicals are generated as by-products of the metabolization of more complex compounds. Vinyl chloride is emitted both from volatilization of vinyl chloride contained in the solid waste and as a result of degradation of trichloroethene and dichloroethene. It also appears that lignin (from woody yard waste) is degraded to a variety of aromatic compounds, eventually forming benzene, toluene, phenols, alcohols and esters. (U.S. EPA, 1991).

Emission controls that provide for 98% NMOC control may still have vinyl chloride emissions that exceed the ASIL, depending on the distance from the fill to the fenceline.

The recommendation for estimating uncontrolled landfill emissions is to use EPA's Landfill2 model (which predicts emissions for 50 years after landfill is full). If the landfill specific rate parameters have not been determined, the landfill regulation requires the use of the parameters in the most recent version of *AP-42*[1].

All of these factors reflect a national average. Many of the landfills used to establish this average are located in arid areas. The “old” factors were based on the worst case emissions from 931 landfills nationwide. The revised values used in the most recent version of the draft regulation and in AP-42 include many more landfills or more tests on specific landfills (58 FR 117).

All of these parameters can be determined experimentally at the landfill, as can specific compound concentrations. EPA has finalized and published testing and analysis methods for these factors (RM 304A and RM 304B, Biodegradation rate, RM 25C, Determination of Nonmethane Organic compounds (NMOC) in MSW Landfill gases, issued and RM 2E, Flow rate from landfill wells).

The uncontrolled emission rates produced by the Landfill2 model should then be adjusted to account for the control efficiency of controls installed.

To estimate landfill emissions using the Landfill2 model, the minimum information needed is the surface area (square meters), maximum depth (meters), average depth (meters), landfill volume (megagrams), year landfill began accepting waste, and the k & L_o factors given in AP-42. Table 1 gives a summary of non-methane organic compounds found in landfill gas.

Solid waste is normally compacted after being placed in the landfill. Normal compaction results in an in-place density of 500 to 1500 lb./cu.yd. An average compaction factor is in the range of 700-900 lb./cu.yd. Most landfills of smaller size (300,000 cu.yd. or smaller) not having a known density or weight of waste received will best be modeled with a conversion of 700 lb./yd. This lower value is due to the smaller size machinery used at these fills which results in a lower level of compaction. The highest level of compaction will be the result of the use of heavy equipment for compacting the waste and/or the use of compacted and baled waste (bale fills). Larger landfills will usually have scales to weigh the incoming waste so a means to convert material volume to compacted weight is not needed.

Bale fills have very high waste densities due to compressing the waste. They exhibit high weight per volume and low gas and liquid porosities. The literature does not indicate whether anyone has determined k and L_o values for a balefill. The best that can be said for balefills is that they will become anaerobic faster once there is adequate moisture in the fill, but it will take longer for that moisture to get into the fill.

[1] U.S. Environmental Protection Agency, *Compilation of Air Pollutant Emissions Factors Volume 1: Stationary Point and Area Sources*, Fifth Edition with Supplements, October 1997, Document No. AP-42.

References

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Washington State Department of Ecology, *Facility/Site on the Web*, accessed 1/20/98. (http://www.wa.gov/ecology/iss/fsweb/fshome.html)

Table 1. Summary of Non-Methane Organic Compounds Found In Landfill Gas **(U.S. EPA, 1991)**

Chemical Name	**No. of Times Quantified**	**Average Conc. ppm**	**Average Conc. Detected ppm**	**Highest Conc. ppm**	**Lowest Conc. ppm**
Ethane	26	142.79	252.63	1780	0
Toluene	40	51.60	59.34	758	0.2
Methylene chloride	37	19.70	24.5	174	0
Hydrogen sulfide	3	16.50	252.97	700	11
Ethylbenzene	31	14.64	21.73	428	0.15
Xylene	2	14.52	333.85	664	3.7
1,2-Dimethyl benzene	1	12.78	588	588	588
Limonene	1	10.22	470	470	470
Total xylene isomers	27	10.04	17.11	70.9	0
Alpha-pinene	1	9.70	446	446	446
Dichlorodifluoromethane	31	8.83	13.1	43.99	0
Etylester butanoic acid	1	8.65	398	398	398
Propane	26	7.68	13.59	86.5	0
Tetrachloroethene	39	7.15	8.43	77	0
Vinyl chloride	42	7.04	7.71	48.1	0
Methylester butanoic acid	1	6.63	305	305	305
Ethylester acetic acid	1	6.13	282	282	282
Propylester butanoic acid	1	5.50	253	253	253
1,2-Dichloroethene	37	5.09	6.33	84.7	0
Methyl ethyl ketone	27	4.80	8.17	57.5	0
Thiobismethane	1	4.57	210	210	210
Methlycyclohexane	2	4.33	99.7	197	2.4
Trichloroethene	44	3.80	3.98	34	0.01
Nonane.	1	3.63	167	167	167
Benzene	45	3.52	3.6	52.2	0
Ethanol	1	3.41	157	157	157
Acetone	26	3.36	5.94	32	0
2-Butanol	1	3.30	152	152	152
Octane	1	3.30	152	152	152
Pentane	26	3.19	5.64	46.53	0
Hexane	26	3.01	5.33	25	0
Methylester acetic acid	1	2.96	136	136	136

Chemical Name	No. of Times Quantified	Average Conc. ppm	Average Conc. Detected ppm	Highest Conc. ppm	Lowest Conc. ppm
1-Methoxy-2-methyl propane	1	2.96	136	136	136
2-Butanone	1	2.80	129	129	129
1,1-Dichloroethane	3	2.52	3.51	19.5	0
1-Butanol	1	2.17	100	100	100
Butane	26	2.08	3.68	32	0
4-Methyl-2-pentanone	1	1.93	89	89	89
2-methyl propane	1	1.83	84	84	84
1-methylethylester butanoic acid	1	1.50	69	69	69
2-methyl methylester propanoic acid	1	1.50	69	69	69
Carbon tetrachloride	37	1.49	1.85	68.3	0
Chloroethane	29	1.28	2.03	9.2	0
1,1,3-Trimethyl cyclohexane	1	1.24	57	57	57
2-Methyl-1-propanol	1	1.11	51	51	51
1,2-Dichloroethane	37	1.05	1.3	30.1	0
Trichlorofluoromethane	46	0.99	0.99	11.9	0
Chloromethane	30	0.90	1.38	10.22	0
2,5-Dimethyl furan	1	0.89	41	41	41
2-Methyl furan	1	0.87	40	40	40
Chlorodifluoromethane	27	0.79	1.35	12.58	0
Propene	1	0.78	36	36	36
Methyl isobutyl ketone	26	0.78	1.38	11.5	0
Ethyl mercaptan	3	0.78	11.93	23.8	1
Dichlorofluoromethane	28	0.73	1.2	36.11	0
1,1,1-Trichloroethane	38	0.69	0.84	9	0
Tetrahydrofuran	1	0.65	30	30	30
Ethylester propanoic acid	1	0.57	26	26	26
Bromodichloromethane	29	0.45	0.71	7.85	0
Ethyl acetate	1	0.43	20	20	20
3-Methylhexane	1	0.43	20	20	20
ClOH16 unsaturated hydrocarbon	1	0.33	15	15	15
Methylpropane	1	0.26	12	12	12
Chlorobenzene	29	0.24	0.38	10	0
Acrylonitrile	26	0.18	0.32	7.4	0
Methylethylpropanoate	1	0.16	7.3	7.3	7.3

Chemical Name	No. of Times Quantified	Average Conc. ppm	Average Conc. Detected ppm	Highest Conc. ppm	Lowest Conc. ppm
1,1-Dichloroethene	32	0.16	0.23	3.1	0
Methyl mercaptan	3	0.12	1.87	3.3	1
1,2-Dichloropropane	28	0.07	.012	1.8	0
i-propyl mercaptan	2	0.07	1.55	2.1	1
Chloroform	36	0.06	0.08	1.56	0
1,1,2,2-Tetrachloroethane	28	0.06	0.1	2.35	0
1,1,2,2-Tetrachloroethene	2	0.06	1.33	2.6	0.05
2-Chloroethylvinyl ether	28	0.05	0.08	2.25	0
t-butyl mercaptan	2	0.03	0.64	1	0.28
Dimethyl sulfide	2	0.02	0.55	1	0.1
Dichlorotetrafluoroethane	1	0.02	1.1	1.1	1.1
Dimethyl disulfide	2	0.02	0.55	1	0.1
Carbonyl sulfide	1	0.02	1	1	1
1,1,2-Trichloro-1,2,2-trifluoroethane	1	0.01	0.5	0.5	0.5
Methyl ethyl sulfide	1	0.01	0.32	0.32	0
1,1,2-Trichloroethane	28	0.00	0	0.1	0
1,3-Bromochloropropane	1	0.00	0.01	0.01	0.01
1,2-Dibromoethane	2	0.00	0	0	0
C-1,3-Dichloropropene	2	0.00	0	0	0
T-1,3-Dichloropropene	2	0.00	0	0	0
Acrolein	26	0.00	0	0	0
1,4-Dichlorobenzene	28	0.00	0	0	0
Bromoform	28	0.00	0	0	0
1,3-Dichloropropane	26	0.00	0	0	0
1,2-Dichlorobenzene	29	0.00	0	0	0
1,3-Dichlorbenzene	29	0.00	0	0	0
Dibromochloromethane	28	0.00	0	0	0
Bromomethane	28	0.00	0	0	0