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Project Summary

Evaluation of Air Emissions from Hazardous Waste Treatment, Storage, and Disposal Facilities

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This study examines the fugitive air emissions from landfills, surface impoundments, storage tanks, containers (drums), solvent recovery processes, and land treatment technologies at Hazardous Waste Disposal Facilities (HWDFs). The main objective was to develop and demonstrate techniques for determining air emissions from the above sources. Various predictive models for estimating air emissions exist for some of these sources. These models have been identified and evaluated for applicability to select HWDFs. Sampling approaches have been identified for measuring the air emissions from these different operations. Procedures for the collection and qualitative and quantitative analysis of the air samples and the liquid and solid samples taken in conjunction with the air samples have also been developed. The resulting analytical data have provided general information on the level of air emissions from the sources studied. This document summarizes the findings from each of four HWDFs tested, comparing and contrasting the measured and predicted emission results and the experiences gained in using the various sampling approaches.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Office of Solid Waste (OSW) is required, under Executive Order 12291, to conduct a Regulatory Impact Analysis (RIA) that will examine costs and benefits for various alternatives to control air emissions from the treatment, storage, and disposal operations at hazardous waste disposal facilities (HWDFs). This study has examined the fugitive air emissions from landfills, surface impoundments, storage tanks, containers (drums), solvent recovery processes, and land treatment technologies at HWDFs.

The main objective of this study was to develop and demonstrate techniques for determining air emissions from the above HWDF technologies (sources). Various predictive models for estimating air emissions exist for some of these sources. These models have been identified and evaluated for applicability to select HWDFs. Sampling approaches have been identified for measuring the air emissions from these treatment, storage, and disposal operations. Procedures for the collection and qualitative and quantitative analysis of the air samples and the liquid and solid samples taken in conjunction with the air samples have been developed. The resulting analytical data have provided general information on the level of air emissions from the sources studied. Specific information has been presented in separate Data Volumes for each of the four sites tested. This document summarizes the findings from

each of these sites, comparing and contrasting the measured and predicted emission results and the experiences gained in using the various sampling approaches.

Predictive Models for Comparison to Air Emission Measurements

Reviews of models for estimating air emissions from hazardous waste treatment, storage, and disposal facilities have been provided to EPA by Radian and GCA. GCA has recommended those models shown in Table 1 for use in predicting emissions from various treatment, storage, and disposal facilities. Data were collected at the sites for input to the models. Where possible, measured values were used as input. Where measured values were not possible, input values were obtained from records, literature values, engineering estimates, etc.

Sampling Approaches for Measuring Air Emissions

The sampling approaches for measuring air emissions from treatment, storage, and disposal facilities (TSDFs) include:

- emission isolation flux chamber,
- vent sampling,
- concentration-profile,
- transect technique, and
- mass balance.

Table 2 presents the sampling approaches identified as applicable to various treatment, storage, and disposal facilities.

Sampling Sites

Six sites were investigated during an initial pretest site survey. The survey was designed to select those sites that had TSDFs most suitable for testing. The recommendations for field testing and results from the initial sampling and analytical efforts are found in the pretest site survey report. Four of these six sites were tested, including Sites 2, 4, 5, and 6.

Testing Program

The field testing conducted at the sites is shown in Table 3. The field testing was performed during the following periods during the Fall of 1983.

- Site 5 - September 30 - October 11,
- Site 4 - October 11 and 12,
- Site 6 - October 24-28, and
- Site 2 - November 14-18.

A systems and performance audit of the on-site sampling and analytical activities was conducted by Radian's Quality Assurance Coordinator on October 5-7.

Table 1. Recommended Air Emissions Models for Hazardous Waste Disposal Facilities

Source	Model(s)
Landfill	*Farmer, et al (1978) - for Covered Landfills* *Thibodeaux (1980) - Landfill Equation--without internal gas generation* *Thibodeaux (1981) - Landfill Equation--with internal gas generation*
Landtreatment	*Hartley Model (1969)* *Thibodeaux-Hwang (1982)*
Surface Impoundment	*Mackay and Leinonen (1975) - Unsteady-State Predictive Model for Nonaerated Surface Impoundments* *Thibodeaux, Parker, and Heck (1981) - Steady-State Predictive Model for Nonaerated and Aerated Surface Impoundments*
Open Tank	*Thibodeaux (1980) - Aerated Surface Impoundment (ASI) Model* *Hwang (1970) - Activated Sludge Surface Aeration (ASSA) Model* *Freeman (1980) - Diffused Air Activated Sludge (DASS) Model*
Storage Pile	*Midwest Research Institute Emission Factor Equations for Storage Piles*
Fixed Roof Tanks	*API (1962), modified by TRW/EPA, Fixed Roof Tank Breathing Losses* *API (1962) - Fixed Roof Tank Working Losses*
Floating Roof Tanks	*API (1980) - Evaporation Loss from External Floating Roof Tanks* *EPA/API (1981) - Standing Storage Losses from External Floating Roof Tanks* *EPA/API (1981) - Standing Storage Losses from Internal Floating Roof Tanks*

Conclusions

The field testing performed in this program has provided data on the air emission rates from a variety of sources within hazardous waste treatment, storage, and disposal facilities (TSDFs). Air emission rates were measured using various approaches and predicted using existing models. Neither the measurement approaches nor the predictive models have been validated, and as such, this program represents a demonstration of these approaches for measuring/modeling emissions from TSDF sources. The measured and predicted emission rates have been compared throughout this report as a relative comparison only. The accuracy of the measured and the predictive procedures are not established. The experiences gained during this program should, however, provide a basis for future field testing of TSDFs.

A summary of the results of the emission rate measurements from the various TSDFs tested is given in Table 4. Only the total nonmethane hydrocarbon (TNMHC) emissions are included in this table. Results are provided for both the entire surface area (kg-C/day) and per unit area (kg-C/hectare-day). The emission rates presented in the table represent an average of all the measurements for a given source. The measurements were made over a relatively short period of time and under specific process operating and meteorological conditions. For these reasons, caution should be used in attempting to extrapolate these data to sources at other TSDFs, or for longer time periods (i.e., annual averages).

The highest emissions measured at an active landfill were encountered during active dumping of the waste (23.1 kg-C/day). Emission rates were lower (1-10 kg-C/day) in areas of the landfills which did not have active dumping concurrent with the measurements. All but one of the landfills tested were very large with multiple cells. Because of the large exposed surface areas, the emis-

sions for the total source were similar in magnitude to the surface impoundments. No measurable emissions were detected through the cover of the inactive landfills tested. Both inactive landfills did however have vents from which emissions were detected (<0.01 kg-C/day). Emissions from the vents were not constant, rather they occurred as puffs with no specific frequency of occurrence.

A variety of surface impoundments were tested, including small surface area receiving ponds (high liquid concentrations) and large surface area polishing ponds (now liquid concentrations). As expected, the emissions from the receiving ponds were higher (order of magnitude) than the polishing ponds on a per surface area basis. Emissions from the total sources were more simi-

Table 2. *Summary of Emission Measurement Approaches for Selected Activities within a Hazardous Waste Disposal Facility*

Activity	*Emission Measurement Approach*[a]	*Comments*
Treatment Plants		
1) Physical, biological and/or chemical treatment units, including continuous mixing in open tanks	*Emission isolation flux chamber*	*Open tanks; little or no surface disturbance*
	Mass balance	*Batch process or steady-state operation/process*
	Transect technique	*Requires minimal interferences from other emission sources; applicable when surface is highly agitated*
	Vent sampling	*Closed tanks*
2) Spraying/aeration and spray irrigation	*Transect technique*	*Requires minimal interferences from other sources; must consider aerosal vs. vapor during sampling collection*
3) Distillation and cracking/refining	*Vent sampling*	
Storage		
4) Open tanks	*See 1) above*	
5) Surface impoundments	*Concentration-profile technique*	*Must meet criteria for the micrometeorological model*
	Transect technique	*Requires minimal interferences from other emission sources; not applicable to large impoundments*
	Emission isolation flux chamber	*Small surface impoundments and/or minimal surface disturbances*
	Mass balance	*Batch process or steady-state operation/process*
6) Evaporation ponds or tanks (unheated and heated)	*See 1) above*	
7) Drum recycling operations	*Transect technique*	*Requires minimal interferences from other emission sources*
	Emission isolation flux chamber	*Bagging of single drums only*
8) Spent drum storage	*See 7) above*	
Disposal Facilities		
9) Landfills (active and inactive)	*Transect technique*	*Requires minimal interferences from other emission sources*
	Emission isolation flux chamber	*Covered landfill only*
	Vent sampling	*Covered landfill with gas collection system*
10) Landtreatment	*Emission isolation flux chamber*	
	Mass balance	*Requires some knowledge of biodegradation rate*
	Transect technique	*Requires minimal interferences from other emission sources*
Fugitive Sources		
11) Vacuum pumps used on tank trucks	*Vent sampling*	
	Transect technique	*Requires minimal interferences from other emission sources*

[a]*Description of emission measurement approaches:*
Emission isolation flux chamber - direct emission measurement, no interference from other emission sources.
Mass balance - indirect emission measurement based upon difference in bulk component concentrations.
Transect technique - indirect emission measurement based upon ambient concentrations downwind from source, other emission sources can interfere with measurements.
Vent sampling - direct emission measurement, no interferences from other emission sources.
Concentration-profile technique - indirect emission measurement based upon ambient concentrations immediately above surface, minimal interference from other emission sources as long as a concentration profile can be measured.

Table 3. *Summary of Field Testing Performed*

Site	Source	Sampling Approach	Model
2	Landfill (active)	Transect technique and Emission isolation flux chamber	No specific model applicable
	Landtreatment	Emission isolation flux chamber and Concentration-profile technique	Thibodeaux-Hwang (1982), Hartley (1969)
4	Chemical Landfill D (active)	Flux chamber	No specific model applicable
	Chemical Landfill C (inactive)	Flux chamber	No specific model applicable
5	Wastewater treatment, Reducing Lagoon 1	Flux chamber	Thibodeaux, Parker and Heck (1983)
	Wastewater treatment, Oxidizing Lagoon 2	Flux chamber	Thibodeaux, Parker and Heck (1983)
	Wastewater treatment, Holding Pond 6	Concentration-profile Flux chamber	Thibodeaux, Parker and Heck (1983)
	Hazardous, non-hazardous drum storage building	Vent sampling	No specific model applicable
	Chemical Landfill 10 (active)	Transect technique Flux chamber	Individual cells, Farmer, et al (1978) Thibodeaux (1980)
	Chemical Landfill 7 (inactive)	Flux chamber Vent sampling	No specific model applicable
6	Distillation Process	Mass balance	No specific model applicable
	Closed Tanks (vented)	Vent sampling	API/EPA (1962)
	Drum Storage and Handling[a]	Transect technique	No specific model applicable
	Spray Evaporation Pond[b]	Transect technique	No specific model applicable

[a]*Testing scheduled, but not performed due to meteorological conditions; qualitative data obtained.*
[b]*Limited testing performed due to meteorological conditions.*

lar due to the differences in size of the ponds, with the receiving ponds (1-7 kg-C/day) being somewhat higher than the polishing ponds (0.4-1.4 kg-C/day).

The highest emissions measured were for the land treatment of oily wastes. Depending on the approach used for making the measurement and the time that the measurement was made after initial spreading of the waste, the emission rates ranged from 3-60 kg-C/day. The waste was surface spread and included daily tilling. Emissions tended to decrease rapidly following the initial application and to increase slightly with each day's tilling.

Emissions during solvent recovery operations for 1,1,1-trichloroethane and methylethylketone (MEK) were at nominally 1% of the throughput for the distillation process. Losses (emissions) during washing of the 1,1,1-trichloroethane were substantially greater (16.7%). Emissions from a drum storage building were measured at 0.2 kg-C/day. Surveys around outside drum storage areas showed measurable TNMHC concentrations, but no emission rates were determined. Measurements of the breathing losses (emissions) from fixed-roof storage tanks were attempted, but no measurable flow from the vents could be detected.

A number of field sampling techniques were used in this study including:

- emission isolation flux chamber
- transect technique
- concentration-profile technique
- vent sampling
- mass balance

As a result of the experience gained in using these techniques, several general statements on the use and limitations of each of the approaches can be made.

The emission isolation flux chamber technique was simple and straightforward to execute in the field. No specific meteorological conditions prevented sampling, with the exception of high winds during tethered operation at some ponds. Field calibration and quality control procedures were readily performed. The statistical sampling approach appears suited to the sampled ponds, landfarm, and some landfills. However, certain of the landfills were quite large and heterogeneous in nature, making the overall representativeness of the limited data obtained suspect in these cases. In general, very good correlations were observed between all components detected from the chamber and the volatile components in the corresponding liquids and solids (waste). The variability in the emission rates determined using the flux chamber was typically much less than the transect, concentration-profile, or predicted emission rates.

The transect technique required more instrumentation and was more labor intensive than the emission isolation flux chamber. The transect technique is very dependent upon and very vulnerable to ambient meteorological conditions, the physical surroundings about the measured source, and the configuration of the source itself. During the testing periods, testing was often prevented due to unacceptable atmospheric stabilities, high/low wind speeds, variable wind direction, and wrong wind direction. Transect testing was precluded at some sites because of the proximity of obstacles that produced air turbulence and prevented proper plume formation. These experiences emphasize the extent to which meteorological dependence can escalate the cost and ability of obtaining emission data using the transect technique. In general, the uncertainty associated with the emission rates estimated by the transect technique are greater than those measured by other methods.

The concentration-profile technique required the most instrumentation and was the most labor intensive of the three sampling approaches. It too is dependent on ambient meteorological conditions and physical configuration of the source. During the field testing, unsatisfactory meteorological conditions resulted in several days' delay and, in some cases, samples of questionable validity. Both the concentration-profile and transect techniques require analysis of air samples which are at least an order of magnitude more dilute than corresponding flux chamber samples. This fact impacts the analytical procedures which can be used with these approaches and the level of compounds which may be de-

tected. The method is also limited to flat, relatively large area sources. The variability in the emission rates determined using the concentration-profile technique was typically greater than with the flux chamber, but better than the transect technique.

It is generally expected that the flux chamber will result in lower measured emission rate than the concentration-profile technique, due to the absence of wind effects in the flux chamber. In comparing the emission rates determined by both methods at the landtreatment area, Site 2, the concentration-profile values were indeed higher than the flux chamber values. The difference, however, may have also been due in part to the time dependence of the emission rates from the landtreatment area and the fact that the concentration-profile measurements were made following tilling (which is expected to temporarily increase the emission rate).

Table 4. *Emission Rates of Total Nonmethane Hydrocarbons from TSDF Sources Measured Using Various Sampling Approaches*

TSDF Source	Sampling Approach	Emission Rate (Kg-C/hectare-day)	Emission Rate (Kg-C/day)
Active Landfill			
Site 5-Landfill 10	*Transect Technique*	*3.8, 9.2[a]*	*9.5, 23.1*
	Emission Isolation Flux Chamber	*4.5[b], 13[b]*	*1.1[b], 8.2[b]*
Site 4-Landfill D	*Emission Isolation Flux Chamber*	*4.1[b]*	*1.6[b]*
Site 2-Landfill Q	*Emission Isolation Flux Chamber*	*0.8[b]*	*0.015[b]*
Inactive Landfill			
Site 5-Landfill 7	*Emission Isolation Flux Chamber*	*<0.1[c]*	
	Vent Sampling		*<0.01*
Site 4-Landfill C	*Emission Isolation Flux Chamber*	*<01.1[c]*	
	Vent Sampling		*<0.001*
Surface Impoundments			
Site 5-Lagoon 1	*Emission Isolation Flux Chamber*	*10*	*1.4*
Site 5-Lagoon 2	*Emission Isolation Flux Chamber*	*49*	*7.1*
Site 5-Pond 6	*Emission Isolation Flux Chamber*	*2.7*	*1.4*
	Concentration-Profile	*0.8*	*0.4*
Site 6-Pond 3	*Transect Technique*	*54[d]*	*2.7[d]*
Solvent Recovery			
Site 6-1,1,1-Trichloroethane	*Mass Balance*	*1.2%[e], 16.7%[f]*	
Site 6-MEK	*Mass Balance*	*1.1%[e]*	
Landtreatment			
Site 2-Landtreatment	*Emission Isolation Flux Chamber*	*626-53[g]*	*35-3[g]*
	Concentration-Profile	*1080-831[h]*	*60.5-46.5[h]*
Drum Storage Building			
Site 5	*Vent Sampling*		*0.2*
Storage Tanks			
Site 6	*Vent Sampling*		*<0.1[i]*

[a]Active dumping of waste.
[b]Single cell of landfill.
[c]Below detection limit.
[d]Validity of data questionable.
[e]Distillation losses only.
[f]Washing losses.
[g]Emission rates measured from time of spreading to two days after spreading.
[h]Emission rates measured from one to two days after spreading.
[i]No detectable gas flow rate.

In contrast, at Holding Pond 6, Site 5, the flux chamber technique resulted in a statistically significant greater air emission rate than was determined by the concentration-profile technique. This phenomenon was not expected, and no explanation is available for this behavior.

As a result of the field studies, the emission isolation flux chamber sampling procedure would appear to be the preferred method of the three sampling methods that were used. It is recommended wherever it is applicable. Situations where the flux chamber may not be applicable are large areas in which some continuing activity is occurring (spreading/tilling of sludge at landtreatment sites, highly agitated surface impoundments, etc.). In these cases, the concentration-profile technique is preferred (even though it is labor-intensive and requires the most instrumentation) for large, relatively flat sources. The transect method is the third choice for those cases where neither the flux chamber nor the concentration-profile are applicable.

The vent sampling techniques which were applied at the test sites were simple and straightforward. However, the low flow rates and intermittent nature of the emissions from both the landfill vents and storage tanks presented problems. These problems were most severe for the storage tank vents, where the velocity was undetectably low. If such sampling is to be done in the future, special apparatus will have to be designed to accurately monitor very low flow rates. Alternatively, a flux chamber could be sealed over the vent and the emissions monitored continuously over a period of time (days).

The mass balances made during the solvent purification runs resulted in a measurable loss, which was attributed to emissions. However, the precision of the calculated emission rate (mass loss) was quite poor. This imprecision is primarily attributed to the imprecision in the liquid level measurements, as well as to the fact that the calculated emission rate is the difference between two large numbers.

The Thibodeaux, Parker, and Heck air emission model was used to predict emissions from Lagoons 1 and 2 and Holding Pond 6 at Site 5. Predicted emissions were compared to emission rates for Lagoons 1 and 2 measured using the flux chamber. No statistically significant differences were determined

between predicted and measured emission rates in half of the cases examined for Lagoon 1. In all other cases, the predicted rate was greater than the measured rate for Lagoon 1. For Lagoon 2, the predicted rate was orders of magnitude greater than the measured rate in all cases. This discrepancy is attributed to problems in modeling the sludge/oil/aqueous surface encountered for this lagoon. Predicted emissions were compared to emission rates for Holding Pond 6 measured using both concentration-profile and flux chamber techniques. In general, the predicted rates are statistically greater than those measured by the concentration-profile technique and less than those measured by the flux chamber.

The Thibodeaux, Parker, and Heck air emission model was also used to predict emissions from the spray evaporation pond at Site 6 due to vaporization of the liquid surface. The model does not include emissions due to vaporization from the spray nozzles and would therefore be expected to predict lower emission rates than would be measured. This was not the case, however. Due to the poor quality of the transect data, the measured data are perceived to have underestimated the true emission rate. However, it should be noted that both the predicted and measured emission rates had very broad confidence intervals, which both included the corresponding mean values and a zero emission rate. The imprecision of the predicted values is attributed to the wide variability in the concentrations of compounds found in the pond samples.

The Thibodeaux-Hwang air emission model was used to predict emissions from the landfarm. The predicted emissions show a time dependence, with the emission rate decreasing exponentially. The effect of retilling the area is to increase emissions initially; however, the emission rate quickly returns to the range of values predicted if no tilling had occurred. The predicted emission rates were compared with the emission rates measured using the flux chamber and concentration-profile techniques. In general, the predicted emissions agreed with the measured emissions for specific compounds, but did not agree with the compound classes and total nonmethane hydrocarbon emission rates. In all cases, the predicted emission rates were significantly greater than the measured emission rates for the compound classes and total nonmethane hydrocarbons. This discrepancy may be caused, at least in part, by the composite parameters which were used for the compound classes. The Thibodeaux-Hwang model was developed for single components. To apply the model to multicomponent compound groups or classes, a set of parameters was developed for each group by averaging the parameter values of the more prominent compounds contained within the group. A more sophisticated approach may be needed to extend the model to multicomponent systems.

Existing predictive models were not used to estimate emissions from the inactive chemical landfills in light of the heterogeneous nature of the waste and inability of the existing models to account for vented emissions.

The API imperical model for breathing losses was used to predict breathing losses from four of the fixed-roof tanks at Site 6. The annual emission rates predicted by the API model were then used to calculate flow rates through the vents. Additionally, vent flow rates were calculated based upon vapor displacement calculations. The flow rates calculated by each method are quite similar, and all were at or below the detection limits for the flow measurement techniques used on site. The field observations and predicted emission rates from the fixed-roof tanks are therefore consistent with each other.

In summary, the Thibodeaux, Parker, and Heck surface impoundment model appears to be generally applicable to individual compounds in impoundments having no oil on the surface and/or no mechanical sprays. The Thibodeaux-Hwang landtreatment model appears to adequately describe the emissions of single compounds. However, it was not found to be satisfactory for compound classes or total NMHC emissions.

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The complete report, entitled "Evaluation of Air Emissions from Hazardous Waste Treatment, Storage, and Disposal Facilities," (Order No. PB 85-203 792/AS; Cost: $11.50, subject to change) will be available only from:
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