United States
Environmental Protection
Agency

Office of
Solid Waste &
Emergency Response

EPA/530-SW-84-008
June 1984

Solid Waste

Assessing the Releases and Costs Associated with Truck Transport of Hazardous Wastes

Executive Summary

This report was prepared by Dr. Mark Abkowitz and Dr. Amir Eiger, Faculty Members, Department of Civil Engineering, Rensselaer Polytechnic Institute, Troy, N.Y., and Mr. Suresh Srinivasan of Transportation Consultants, for the U.S. Environmental Protection Agency and ICF Incorporated under contract.

The report has been reviewed by the U.S. Environmental Protection Agency (EPA) and approved for publication. Its publication does not signify that the contents necessarily reflect the views and policies of the U.S. EPA, nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. government.

ASSESSING THE RELEASES AND COSTS ASSOCIATED WITH TRUCK TRANSPORT OF HAZARDOUS WASTES

EXECUTIVE SUMMARY

This report was prepared for
the Office of Solid Waste under
contract no. 68-01-6621

U.S. ENVIRONMENTAL PROTECTION AGENCY
Washington, D.C.

Preface

This report presents an analysis which estimates the releases from and costs of transporting hazardous wastes. These estimates will be included in a larger, more general analysis of hazardous waste management, namely, the Office of Solid Waste "RCRA Risk-Cost Analysis Model." The complete report on the transportation analysis will be available from the National Technical Information Service (NTIS), Springfield, Virginia 22161. Single copies of the Executive Summary (including the Table of Contents to the entire report) are available directly from EPA.

TABLE OF CONTENTS

ACKNOWLEDGEMENT

The authors would like to acknowledge the advice, guidance and cooperation of Curtis Haymore, Arline Sheehan and Eric Malès of the Office of Solid Waste, U.S. Environmental Protection Agency. The assistance provided by Joseph Kirk, Leslie Kostrich, Stephen Bailey and Jean Tilly of ICF Incorporated is also sincerely appreciated. Finally, substantial and useful comments during the review process were made by Russell Cappelle of American Trucking Associations, Inc., Joseph Nalevanko of the U.S. Department of Transporation's Materials Transportation Bureau and John Thompson of the Office of Solid Waste, U.S. Environmental Protection Agency.

EXECUTIVE SUMMARY

In response to a growing concern over the management of hazardous wastes and their impact on the population and environment, the Resource Conservation and Recovery Act (RCRA) was enacted in 1976. RCRA authorized the EPA to establish a hazardous waste control program for the nation, which includes the identification and classification of hazardous wastes, requirements for owners and operators of hazardous waste facilities, and guidelines for state programs developed under the act.

In 1981, as part of the national hazards waste control program, EPA's Office of Solid Waste began to develop its RCRA Risk/Cost Analysis Model. The model is designed to assist in the development of hazardous waste policies.

The RCRA Risk/Cost Analysis Model consists of an array of possible ways to treat, transport and dispose of the hazardous wastes generated in the United States. There are three main factors considered in the model's formulation of possible ways to manage hazardous waste:

(1) The type of waste (and its hazardous chemical constituents).

(2) The types of technologies used to treat, transport and dispose of the wastes.

(3) The environmental settings in which the wastes are treated, transported and disposed.

The model forms all possible combinations of a list of wastes, technologies and environmental settings -- or W-E-T cells. The model then calculates the risks and costs involved in each W-E-T cell. In this fashion, the relative merits and drawbacks of various hazardous waste management strategies can be identified.

This report focuses on one component of the RCRA Risk/Cost Analysis Model: the costs incurred and expected fraction released (R_{tr}) during transport of hazardous wastes. The objectives of our project were governed by the following criteria:

- In order to establish a tool for policy analysis, we wanted to estimate a fraction release model that reflected, as much as possible, actual data on hazardous waste shipments and incidents. Compiling a comprehensive data sample necessitated extensive data collection at both the state and federal levels.
- In order to ascertain whether previous studies were reliable for policy analysis, we performed a critical review of existing truck transport cost studies. We then developed revised cost formulas to account for deficiencies identified in the review process and compared the revised cost procedure with quoted rates to validate its applicability.

Because 90 percent of all current hazardous waste transport is via truck, the transport release model and cost review were restricted to truck transport.[1]

----

[1]The authors are presently conducting studies of the release rates and costs of hazardous waste shipments by rail and waterborne transport.

Fraction Release Analysis Methodology

Hazardous waste releases during transport can result from a number of causes (failures modes) and can occur either at shipping terminal points or enroute. We defined three incident types:

(1) Container failures due to vehicular accidents enroute.

(2) Container failures occurring enroute due to causes other than vehicular accidents.

(3) Container failures at shipment terminal points.

We formulated a Transport Release Model to compute the expected fraction released (R_{tr}) during transport. This is a function of: (1) the expected fraction released enroute and (2) the expected fraction released at terminal points. Deriving these release fractions requires an understanding of the expected fraction released given an incident for each failure mode, the probability of an incident for each failure mode and, for enroute incidents, the distance shipped. It is necessary to estimate these parameters for each container type used in transport. Thus, the total number of parameters to be estimated depends on the number of container types and failure modes. Furthermore, the use of the model for policy analysis requires hazardous waste shipment distances as input.

Estimating incident probabilities also requires a determination of the total involvement. For example, total involvement for incidents which occur enroute is a function of the total distance shipped (i.e., the average shipment distance multiplied by the number of shipments). For incidents which occur at terminal points, the total involvement is the total number of shipments. Thus, it is necessary to estimate the average shipping distance and the number of shipments for each container type.

We computed these measures using: (1) shipping distances derived from incident data, 2) data on the number of vehicular accidents and 3) independently derived estimates of vehicular accident rates. Subsequently, it became possible to compute incident rates for other failure modes. It was not necessary to perform this explicitly for each container type. Rather, we expressed all incident rates in terms of a common vehicle accident rate. We assumed that this accident rate does not depend on the container type used for shipment.

Data Description

We identified three types of data which were necessary to conduct the release and cost analyses:

(1) Truck accident and volume data.

(2) Hazardous waste shipment information.

(3) Hazardous waste incident data.

Wherever possible, we obtained data from 1980, 1981 and 1982, because they represent the most recent information available on hazardous waste incidents and shipments.

We obtained truck accident and volume data from Texas, California and New Jersey records. Each record included average daily counts of vehicular traffic characterized by vehicle type and the annual number of truck accidents. The California and Texas data included observations for interstate highways, U.S. highways and state routes. The New Jersey data, on the other hand, included many highway sections containing intersections with traffic signals.

We collected data on hazardous waste shipments from California, Texas, Massachusetts and New York manifest records. In general, each record contained the following information: origin location, destination location, waste type transported, quantity shipped and unit of shipment. A significant problem with this database was its lack of accuracy in reporting the locations of generation and disposal sites. In some cases, the county of origin or the destination state was the only location description. Thus, it was necessary to make some assumptions to correct for this problem. State data also did not consistently include interstate shipments.

The primary data source for estimating the incident probability and fraction release parameters was the Hazardous Material Incident File (HAZMAT) maintained by the U.S. Department of Transportation's Materials Transportation Bureau (MTB). HAZMAT, a compilation of nationwide data on hazardous material spills, contains information on the frequency and circumstances (container involvement, failure mode, severity of resulting spills, etc.) surrounding hazardous material incidents.

Although over 8,000 incidents of hazardous material spills involving truck travel were reported in 1981, a closer inspection of these data indicated that an extremely small number (84) of these spills involved hazardous wastes. Because the sample size of hazardous waste incidents was not large enough for statistical analysis, we considered all of these hazardous materials incidents in developing the incident model. Also, because we postulated that the incident rate and fraction release models do not depend on the type of waste being shipped, but rather, on the container type used, and because the HAZMAT file covers a wide range of container types, this approach is justified.

Estimating the Truck Accident Rate

We assumed that the truck accident rate is a function of the highway type and traffic conditions. Truck accident and volume data were obtained from California, Texas and New Jersey; these data represented a wide range of traffic and truck volumes and four different highway types. To test the statistical significance of any differences in accident rates under different highway and traffic conditions, we conducted an analysis of variance (ANOVA), which indicated the significance of the traffic volume, truck percentages and highway type.

The analysis of the accident rate data yielded the following estimate for aggregate accident involvement rates (releasing accidents per million truck miles):

Interstates	0.13
U.S. and State Highways	0.45
Urban	0.73
Composite	0.28

These results fall within the range of previously reported estimates and demonstrate the difference in the accident rate for various highway types. The truck accident rate is also dependent on both the total traffic volume and the percentage of trucks in the traffic stream. These results suggest that in applying the estimates provided, cell means should be used in lieu of aggregate means if sufficient information is available to identify the highway type and the traffic volume.

Incident Modeling

The HAZMAT file of reported hazardous materials incidents allows the coding of up to 334 container types and 27 failure modes. From our analyses of these data, we identified 8 container types with reasonably uniform physical characteristics and incident involvement rates:

(1) Cylinders

(2) Cans

(3) Glass

(4) Plastic

(5) Fiber Boxes

(6) Tanks

(7) Metal Drums/Pails

(8) Open Metal Containers

For each of these container classes, we determined the respective parameters in the fraction release model. Table 1 summarizes the resulting estimates of the fraction released by container type.

The results of our analyses indicate that in terms of their order of magnitude, the expected fractions released per mile shipped range from 10^{-8} to 10^{-6}, depending on the container class. The expected fractions released at terminal points range from 10^{-6} to 10^{-3}, depending on the container class.

Table 1 Estimates of Fraction Released by Container Class

Container Class	Expected Fraction Released Per Mile Shipped**	Expected Fraction Released at Terminal Points
1	$1.3 \times 10^{-6} + (.13\ \lambda')$	1.4×10^{-4}
2	$2.6 \times 10^{-6} + (.12\ \lambda')$	4.0×10^{-4}
3	$1.7 \times 10^{-6} + (.27\ \lambda')$	2.6×10^{-4}
4	$4.1 \times 10^{-6} + (.14\ \lambda')$	5.2×10^{-4}
5	$1.3 \times 10^{-6} + (.12\ \lambda')$	6.1×10^{-5}
6	$4.2 \times 10^{-8} + (.19\ \lambda')$	7.6×10^{-6}
7	$2.4 \times 10^{-6} + (.10\ \lambda')$	2.9×10^{-4}
8*	7.5×10^{-6}	1.2×10^{-3}

*estimate associated with the release fraction during accident is not reliable.

**λ' = releasing vehicle accident rate.

Our computed estimates indicate that:

(1) The release rates for tank trucks are much lower than for other container types.

(2) The expected amount released at terminal points is one to three orders of magnitude higher than the amount released enroute.

(3) The expected release fractions during transport are potentially as high as the release fractions at disposal sites and treatment facilities, which range from 10^{-7} to 10^{-3} for routine spillage and 10^{-5} to 10^{-3} for accidental spillage.

Estimating the Expected Amount Released

Using the model parameters given in the previous sections, we employed the following procedure to estimate the expected fraction released during transport:

(1) Identify shipment characteristics.
  - number of shipments
  - volume per shipment
  - trip distance
  - container type

(2) Identify highway characteristics.
  - highway type
  - traffic volumes

(3) Select appropriate values of fraction release parameters for the container type being considered.

(4) Compute the fraction of accidents that involve releases

(derived as the truck accident rate multiplied by 0.2).

(5) Determine fraction released enroute and at terminal points.

(6) Multiply fraction released enroute by total trip miles and fraction released at terminal points by the number of shipments.

(7) Add these values to arrive at total expected fraction released.

(8) Multiply this by the total volume to obtain the total expected amount released.

This procedure is demonstrated in the discussion on model application.

Estimating the Cost of Transporting Waste

Trip Profile Analysis

Using the waste shipment data from Texas, California, Massachusetts and New York, we examined the following:

(1) The mean shipping distance, segmented by waste type (for each state).

(2) The quantity shipped, segmented by waste type (for each state).

(3) The extent to which the above measures vary across states.

The resulting information was used in cost applications where specific trip lengths and the quantities shipped were not known.

In order to determine if the quantity and/or distance shipped is related to the waste type (solid or liquid) or the particular state under consideration, we conducted a multivariate analysis of variance.

The results of the analysis indicated that the shipment characteristics of liquid and solid wastes vary by state and consequently we could not derive aggregate estimates. This resulted in our conducting separate analyses for each state.

Our analysis results indicated that trip distance and quantity shipped vary by waste category and also vary considerably among states. This is likely due to differences in the manifest system, geographic location, size and industrial activity of each state.

We did, however, conclude that the quantity transported is independent of trip distance. Our findings do not substantiate the argument that shipments are filled closer to capacity on longer trips than shorter ones. We also found that in three of the four states, the mean shipment size for liquids is larger than for solids shipments, and that in three of the four states, the average trip distance is longer for solids shipments than for liquids shipments.

Questions are sometimes raised regarding general waste shipment characteristics for the United States. Although there is no basis for assuming that our sample is typical of the entire hazardous waste transport industry, we computed weighted averages of the shipping distances and quantities which reflect the number of annual manifests in each of the states. These weighted averages should not be misinterpreted to apply to specific hazardous waste transport scenarios in the United States.

The mean trip length for all shipments is 84.2 miles, with a mean trip length for liquids of 77.1 miles and for solids of 109.6 miles. For liquids, the mean quantity shipped is 3,171 gallons. For solids, it is 2,791 gallons (11.6 tons). The trip distance frequency distribution for all four states, for both liquids and solids, follows an exponential distribution. This is not surprising because disposal sites are likely to be located near points of waste generation.

Cost Methodology

We reviewed the existing literature on the cost of transporting hazardous waste and identified seven studies which treated the issue of estimating the cost of transporting hazardous waste by truck. All seven studies considered this issue within the larger framework of the total cost and risk of hazardous waste treatment at a regional level.

The studies' results varied from gross estimates of the unit cost of transport to more sophisticated derivations of costs based on fixed and variable components. We noted several deficiencies in these methods, particularly in the assumptions relating to shipment characteristics (for example, all of the studies assumed that vehicles travel at capacity, which is not substantiated by the results of the trip profile analysis) and their failure to compare their results to the actual rates charged by haulers.

Using the most comprehensive of the methodologies, we developed a revised costing procedure which was designed to overcome these deficiencies. Our modifications included considering trip distances and shipment sizes based on the trip profile analysis results, using 1983 component costs, and comparing the revised methodology to actual price quotes from waste haulers.

We then used the revised costing procedure to estimate transport costs for 6,000 gallon tankers and 18-ton stake (flatbed) trucks. The average costs computed using the trip profile characteristics are:

	Tankers	Stake Trucks
Average Cost Per Loaded Mile ($)	$4.14	$4.55
Average Cost Per Loaded Ton-Mile ($)	$0.31	$0.39

The average costs per loaded mile and loaded ton-mile are larger for stake trucks than tankers. This is due to the smaller loads associated with stake trucks.

In order to estimate the cost of transport when details on specific shipments are available, we derived the following formulas for tankers and stake trucks:

$$clm_{tanker}\ (\$/\text{loaded mile}) = 3.08 + \frac{88.8}{X}$$

$$cltm_{tanker}\ (\$/\text{loaded ton-mile}) = \frac{3.08}{Y} + \frac{88.8}{XY}$$

$$clm_{stake}\ (\$/\text{loaded mile}) = 3.02 + \frac{129.38}{X}$$

$$cltm_{stake}\ (\$/\text{loaded ton-mile}) = \frac{3.02}{Y} + \frac{129.38}{XY}$$

where:

clm = cost per loaded mile

cltm = cost per loaded ton-mile

X = shipment distance (miles)

Y = shipment size (tons)

To determine the accuracy of the revised costing procedure, we compared its estimates with the actual rates charged by haulers. The comparison showed that the estimates we obtained using this cost formula appear to be quite representative of quoted rates in the hazardous waste transport industry. The average cost figures, however, did not compare quite as favorably. Consequently, we recommend that the average cost figures should be used rather carefully, and should only be employed when information is not available on trip distance and/or shipment size.

Model Application

To illustrate the established release and cost procedures, we posed the following problem:

Suppose 200 55-gallon drums are being shipped a distance of 100 miles on interstate highways. The average daily traffic (ADT) and truck percentages on the highways are unknown. What are the expected releases and cost involved?

Release Computation

From previously reported results, we obtained the releasing accident rate for interstates as 0.13×10^{-6} releasing accidents per truck mile. The expected amount released enroute was obtained using the fraction released from Table 1 as:

$$E\ (\text{release enroute}) = (2.4\times10^{-6} + 0.10\times0.13\times10^{-6}) \times 100 \times 200 \times 55$$
$$= 2.65 \text{ gallons}$$

E (release at terminals) = $2.9 \times 10^{-4} \times 200 \times 55$

= 3.19 gallons

Total expected release = 5.84 gallons

Cost Analysis

The average load carried by stake trucks is 2,791 gallons, which is equivalent to 11.6 tons. The quantity being shipped is 11,000 gallons, which is equivalent to 45.83 tons. The cost per loaded ton-mile is:

$$cltm_{stake}\ (\$/\text{loaded ton-mile}) = \frac{3.02}{11.6} + \frac{129.38}{(100)(11.6)} = 0.37$$

Number of ton-miles per shipment = 11.6 x 100 = 1160

Cost per shipment = 1160 x 0.37 = $429.20

Average number of shipments = 3.94

Total Cost = 3.94 x 429.20 = $1,691.05

Concluding Remarks

This project has addressed the potential releases and costs of transporting hazardous wastes by truck. In the course of conducting this study, we drew several conclusions that are useful for policy analysis. Below, we briefly discuss our conclusions.

A trip profile analysis conducted on data from several states indicated that, on average, wastes are shipped less than 100 miles from their generation to their disposal sites. The average trip length is lower for liquids than for solids. Generally speaking, the mean quantity shipped is independent of shipping distance.

In assessing truck transport releases, it is important to distinguish between two kinds of incidents that result in spills. For one class of incidents, the probability of occurrence is a function of the distance traveled; for the other, the occurrence probability for a particular shipment is fixed. We computed expected fraction release estimates for both kinds of incidents.

The costs of transporting hazardous wastes by truck can be reasonably approximated using the formulas derived in this study. These cost formulas compare well with actual industry quotes.

The individual and collective results of the entire analysis are applicable at many levels of aggregation. Using this study's models and cost formulas, it is possible to obtain broad estimates of expected releases and transport costs, as well as estimates of the releases and costs involved in individual shipments.

Perhaps the most important result of this study is that the release rates associated with transporting hazardous wastes by truck appear to be as large as the potential releases at treatment and disposal sites. In fact, for some W-E-T combinations, transport may be a potentially more dangerous activity. As a result, policymakers should give careful consideration to the relative risks involved in the treatment, transport and disposal of hazardous wastes.