# Study of Evacuation Times Based on Recent Accident History
SAND94-2590

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## ABSTRACT

A key parameter in the calculation of accident dose-risks by the RADTRAN 4 code is the time assigned for evacuation of the affected area surrounding the accident. Currently, in the interest of assured conservatism, this time is set at 24 hrs. Casual anecdotal evidence has indicated that this value is overly conservative and results in assignment of overly conservative estimates of accident dose-risk. Therefore, a survey of recent truck accidents involving various hazardous materials which required evacuation of surrounding populations reported in various news media was undertaken. Accounts of pertinent scenarios were gleaned from databases citing newspapers and other periodicals, and the local authorities involved in each were contacted to get details of the evacuation including time required.

This paper presents the data obtained in the study and the resultant mean evacuation time plus limits and factors influencing specific results together with conclusions regarding the appropriate value to be used in the RADTRAN 4 code.

## INTRODUCTION

The RADTRAN 4 computer code, which calculates estimates of accident dose-risk corresponding to specified transportation scenarios, ascribes doses to potentially exposed members of the public. These persons are modeled as not being evacuated from the affected area for 24 hours following a release of radioactive material. Anecdotal evidence has suggested that this value may be unnecessarily conservative; consequently risk estimates are unnecessarily high. A survey of recent trucking accidents, reported in newspapers and other periodicals (1988 through 1994), that involved evacuation of the general population in the affected areas was undertaken to establish the actual time required for such evacuations. Accidents involving hazardous materials other than those which are radioactive (e.g., gasoline, insecticides, other chemicals) but also requiring evacuations of nearby residents were included in the survey in order to obtain a statistically significant sample size. A total of 25 references (including some duplications) to incidents in the United States was found; approximately half of them could be sufficiently documented for inclusion in the analysis of evacuation time reported here.

## DATA COLLECTION

* This work was supported by the U. S. Department of Energy under Contract DE-AC04-94AL85000.

An initial collection of abstracts was obtained from searches of a computer database, available through CompuServe®, which included abstracts of newspapers and periodicals published in the U.S. and internationally. From this group, a subset of 25 abstracts was identified which met the criteria of the study: evacuation of the general public from areas surrounding truck accidents involving hazardous materials. Using the information included with the abstracts, local authorities were contacted to obtain details of each incident including the amount of time required, the number of people, the size of the area, and other details as they were volunteered. In some cases, no record of the evacuation time was available, but verbal accounts were obtained from involved agency personnel to corroborate or correct the press accounts. Generally, it was found to be essential to verify or correct press accounts of incidents by contacting local authorities, e.g., the number of people evacuated was often a factor of 2 greater in press reports than the number given by authorities. Also, the data included in official accident reports do not consistently include details of the evacuation, e.g., highway accident reports primarily provide information on traffic/roadway details, injuries/fatalities, and responding personnel. The final list of incidents analyzed qualitatively and statistically in this study consisted of 13 accidents for which data judged reliable were obtained. Table I lists these incidents, pertinent data obtained, and derived parameters.

In the course of discussions with local authorities, information relating to non-truck accident emergencies requiring evacuations was obtained. All except one occurred at a fixed location such as a chemical plant; the exception was a train accident in Mississauga, Ontario, Canada. These additional cases are tabulated in Table II.

## ANALYSIS

Inspection of the data revealed that the time required for an evacuation was influenced by population density, location of the population (e.g., residential, business, industrial, school) and perception of the urgency by the affected public. This can be seen from a comparison of Case A1 (suburban setting) with Case Q (rural setting) listed in Table I or comparison of Case A1 with Case --, in which 3200 of the 5200 evacuees were students at four schools. In addition, some evacuations occurred in stages spaced over times which were longer than the actual time required to evacuate groups once the decision to clear an additional area was made. For this initial evaluation of evacuation data, total number of people and total time were tabulated; differences in details of the evacuations were ignored.

Averaging the evacuation times in Table I yielded a value of 2.0 hours with a standard deviation of 2.6 hours; including the values in Table II changes these values to $3.9 \pm 6.8$ hours. If the exceptionally large evacuation of Mississauga, Ontario, Canada (250000 people) is excluded, the average is 2.8 hours with a standard deviation of 5.0 hours.

A histogram of the evacuation times listed in Table I is plotted in Figure 1. Adding the times from Table II yielded a histogram which is not significantly different in shape over the region where they overlap. The general shape of these plots suggests a lognormal distribution, as may be seen from Figure 2 which displays normalized (at 10 hours) graphs of the two histograms and an approximate fit of a lognormal distribution. The roughness of the fit is attributed to the sparse

data in the two histograms; more precise definition of the actual distribution of evacuation times using a larger sample of data would make a more precise fit feasible.

## CONCLUSIONS

Three conclusions were drawn from this preliminary study:

1) Adding data describing evacuations resulting from incidents at fixed sites to trucking accidents does not significantly alter the distribution of evacuation times.

2) Average evacuation times derived from the data obtained to date are substantially shorter than the value of 24 hours currently used in RADTRAN 4 analysis.

3) The longest evacuation time (23 hours) obtained indicates that the 24-hour value is in fact a properly selected conservative value.

In addition, since the histograms in Figure 1 do not suggest normally distributed evacuation times, a better definition of the distribution, allowing more precise statistical inferences to be drawn, is needed. Calculation of risk estimates based on values of evacuation time randomly sampled from such a distribution would provide an improved representation of accident-related risks. Since fixed-site and rail-accident data appear to have the same type of distribution, a broader search of news abstracts, including evacuations for incidents other than truck accidents, will be undertaken to increase the statistical significance of the derived distribution of evacuation times.

## FIGURE CAPTIONS

Figure 1 - Histograms of Evacuation Times

Figure 2 - Normalized, Cumulative Histograms and LogNormal Distribution

**Table I - Applicable Truck Accidents Requiring Evacuation of the General Public**

| Case | Evacuated Population (persons) | Evacuation Radius (miles) | Population Density* (p/sq.mi.) | Evac. Time (hours) | Evac. Rate (pers/hr) |
|---|---|---|---|---|---|
| Q | 30 | 4 | 1 | 1 | 30 |
| M | 10 | 0.5 | 13 | 0.33 | 30 |
| J | 300 | 2 | 24 | 10 | 30 |
| P | 100 | 1 | 32 | 1 | 100 |
| I | 200 | 1 | 64 | 1 | 200 |
| B | 300 | 1 | 96 | 1 | 300 |
| H | 300 | 1 | 96 | 1 | 300 |
| K | 90 | 0.5 | 115 | 0.5 | 180 |
| E | 1000 | 1.5 | 142 | 4 | 250 |
| -- | 5200 | 2.5 | 265 | 2 | 2600 |
| O | 120 | 0.25 | 611 | 0.75 | 160 |
| X | 1500 | 0.5 | 1911 | 2 | 750 |
| A1 | 200 | 0.06 | 17693 | 1 | 200 |

* Evacuated Population divided by the area defined by Evacuation Radius.

**Table II - Other Incidents Requiring Evacuation of the General Public**

| Case | Evacuated Population (persons) | Evacuation Radius (miles) | Population Density (p/sq.mi.) | Evac. Time, (hours) | Rate (pers/hr) |
|---|---|---|---|---|---|
| F1 | 20 | 1 | 6 | 1 | 20 |
| F2 | 25 | 0.5 | 32 | 0.75 | 33 |
| F3 | 500 | 2 | 40 | 20 | 25 |
| -- | 250000 | 3.8 | 5514 | 23 | 10870 |
| A2 | 60 | 0.04 | 11943 | 0.5 | 120 |
| A3 | 100 | 0.04 | 19904 | 0.5 | 200 |

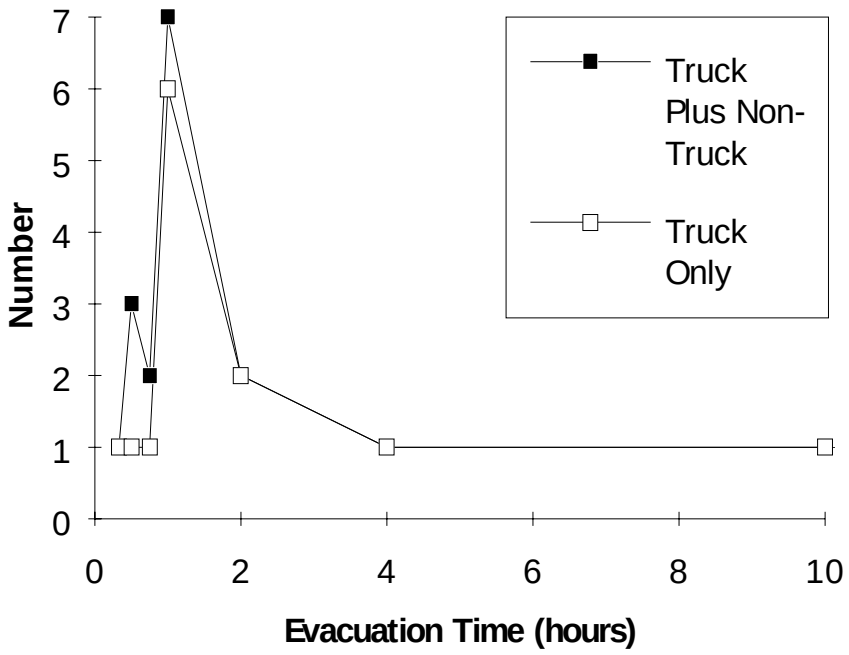


**Figure 1 - Histograms of Evacuation Times**

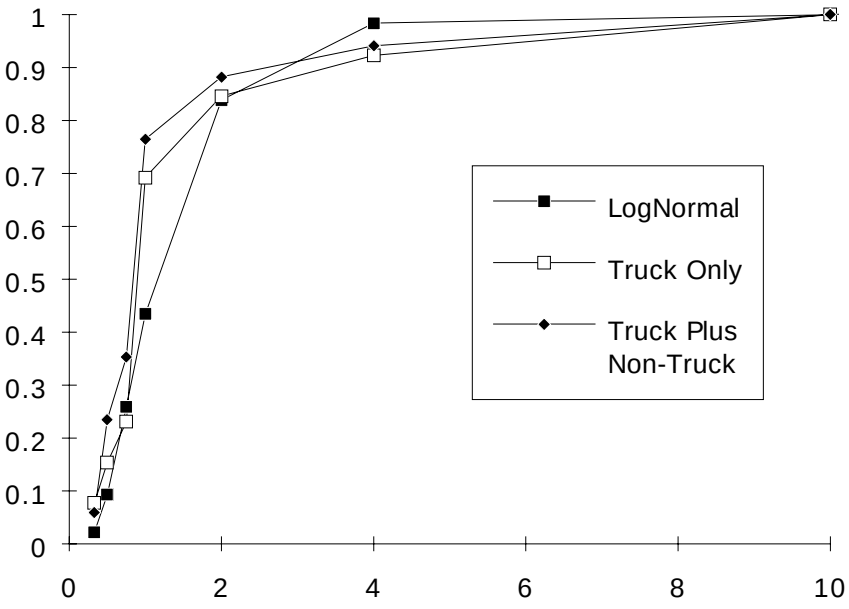


**Figure 2 - Normalized, Cumulative Histograms and LogNormal Distribution**