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Study of Evacuation Times Based on General Accident History

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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. An initial 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. However, the resultant set of sufficiently documented trucking incidents yielded rather sparse data [1]. When the probability density distribution of the truck accident data was compared with that resulting from addition of four other (rail and fixed site) incidents, there was no statistically significant difference between them. Therefore, in order to improve the statistical significance of the data set, i.e., maximize the number of pertinent samples, a search for evacuations resulting from all types of accidents was performed. This resulted in many more references; a set of 48 incidents which could be adequately verified was compiled and merged with the original two data sets for a total of 66 evacuation accounts.

DATA COLLECTION

References to evacuation incidents were obtained from searches of computer databases, available through CompuServe®, containing abstracts of articles in U.S. and international newspapers and periodicals. Using the information included with the abstracts, two of the

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authors (GSM and JDS) contacted local authorities 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. Because of reliance on personal recollection in many instances, little useful data were obtained from references more than 5 to 7 years old, and a higher percentage of incidents in small communities were verified than in metropolitan areas. Table 1 lists the 66 verified incidents, pertinent data obtained, and derived parameters.

ANALYSIS

In the initial study [1], histograms of the evacuation times without any scaling or other adjustments had suggested a lognormal distribution. Therefore, a histogram of the new, larger set of data was extracted and integrated to create a cumulative distribution of the evacuation times which could be fitted with an analytically calculated lognormal distribution. Figure 1 presents the cumulative distribution of the 66 data points and a best fit to the data with a lognormal distribution. The Standard Deviation of the data relative to the fitted lognormal distribution is 3.6%, a good fit given the expected uncertainty in a sample size of 66 (i.e., 12%). One should note that evacuations often occurred in stages spaced over times that were longer than the actual time required to evacuate a group once the decision to clear an additional area was made. Furthermore, inspection of the data and interview notes revealed several factors which appeared to influence the evacuation times: population density, population locations (e.g., residential, commercial, high-rise buildings, rural), public's perception of the danger, night time or day time, rush hour or business hours, etc.

CONCLUSIONS

The general conclusion that may be drawn is: regardless of the variability in details of the evacuations examined, the unadjusted total evacuation times are accurately modeled by a lognormal distribution. This makes incorporation of the results into a probabilistic analysis, in which RADTRAN is used in conjunction with Latin Hypercube Sampling (LHS) [2], relatively simple. LHS of the lognormal distribution yields an appropriate range of values for multiple RADTRAN input files in place of a single point estimate. The resultant distribution of RADTRAN accident-risk estimates has a mean that corresponds to an evacuation time of approximately 1 hour (approximately equal to the mode or maximum of the lognormal probability density function) and a standard deviation which takes into account a maximum time exceeding the current conservative point estimate of 24 hours.

Observations based on this study which suggest areas for further study are (1) that evacuation rate (persons/hour) and population density (persons/ km^2) are only loosely correlated. (2) Evacuations of children from schools in threatened areas are assigned the highest priority and have the highest evacuation rates. (3) With regard to the effect of perceived danger on evacuation times, it may be assumed that notification of a radiological hazard will be equivalent to sighting of a large fire hazard in its effect on the threatened population and that evacuation will be prompt. (4) Time of day, as it relates to the activities of the average population, influences the speed with which people respond to an evacuation notice and the rate at which they can move out of the endangered area.

REFERENCES

1. Mills, G. S., Neuhauser, K. S., "Study of Evacuation Times Based on Recent Accident History," Proceedings of Waste Management 95, WM Symposia, Tucson, AZ, March 1995.

2. Iman, R. L. and M. J. Shortencarier, "A FORTRAN Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models," NUREG/CR-3624, SAND83-2365, Sandia National Laboratories, Albuquerque, NM, March 1984.

Table I - Applicable Accidents Requiring Evacuation of the General Public

Case	Evacuated Population (persons)	Evacuation Radius (miles)	Populatio Density* (p/sq.mi.	Evac. Time (hours)	Evac. Rate (pers/hr)
<A1>	200	0.06	17693	1	200
<A2>	60	0.04	11943	0.5	120
<A3>	100	0.04	19904	0.5	200
<B>	300	1	96	1	300
<E>	1000	1.5	142	4	250
<F1>	20	1	6	1	20
<F2>	25	0.5	32	0.75	33
<F3>	500	2	40	20	25
<H>	300	1	96	1	300
<I>	200	1	64	1	200
<J>	300	2	24	10	30
<K>	90	0.5	115	0.5	180
<M>	10	0.5	13	0.33	30
<O>	120	0.25	611	0.75	160
<P>	100	1	32	1	100
<Q>	30	4	1	1	30
<X>	1500	0.5	1911	2	750
<->	250000	3.8	5514	23	10870
<-->	5200	2.5	265	2	2600
A(1)	2000	0.21	14,435	1	2000.0
A(2)	10000	0.04	1,989,437	4	2500.0
B	250	0.05	31,831	6	41.7
C(1)	15	0.50	19	0.33	45.5
C(2)	40	0.56	41	0.75	53.3
C(3)	400	0.56	406	0.75	533.3
C(4)	300	0.56	304	2	150.0
D	2500	0.07	162,403	0.1	25000.0
E(1)	27000	1.43	4,203	4.58	5895.2
E(2)	1000	1.00	318	1	1000.0
H	1000	0.13	18,835	0.25	4000.0
I	24	0.06	2,122	0.25	96.0
N	3000	2.53	149	6	500.0
O	1500	0.17	16,521	0.75	2000.0
P	20	0.25	102	0.33	60.6
Q(1)	400	0.01	1,273,240	0.08	5000.0
R	400	0.10	12,732	1.5	266.7
T	6000	1.13	1,496	1.5	4000.0
W(2)	500	0.56	507	0.5	1000.0
Y(1)	200	0.50	255	1	200.0
Y(2)	50	0.10	1,592	0.75	66.7
AA(1)	300	0.14	4,872	0.5	600.0
AA(2)	7000	1.00	2,228	3	2333.3

Table I - Continued

Case	Evacuated Population (persons)	Evacuation Radius (miles)	Populatio Density* (p/sq.mi.	Evac. Time (hours)	Evac. Rate (pers/hr)
AA(3)	20000	2.00	1,592	4	5000.0
AD	15000	0.56	15,225	2	7500.0
AI	1700	1.00	541	3	566.7
AJ	100	0.56	101	1	100.0
AM	120	0.10	3,820	0.33	363.6
AO	800	0.08	39,789	0.13	6153.8
AQ	40	0.20	318	0.25	160.0
AS	50	0.08	2,487	0.5	100.0
AU(1)	5000	0.56	5,075	1.5	3333.3
AU(2)	1000	0.50	1,273	1	1000.0
AW	200	0.50	255	0.33	606.1
AX	250	1.52	34	1	250.0
AY(1)	49	0.13	998	0.25	196.0
AY(2)	36	0.25	183	0.5	72.0
BC	3000	0.56	3,045	3	1000.0
BF(2)	140	0.50	178	3	46.7
BI(1)	30	0.01	95,493	0.33	90.9
BI(2)	10	0.01	31,831	1	10.0
BI(3)	600	0.02	477,465	0.16	3750.0
BJ(1)	150	0.50	191	1	150.0
BJ(2)	400	1.25	81	2.5	160.0
BK	10000	0.29	37,849	10	1000.0
BL	250	0.03	88,419	5	50.0
BM	1200	2.00	95	4	300.0

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

< > Designates Data from Initial Study

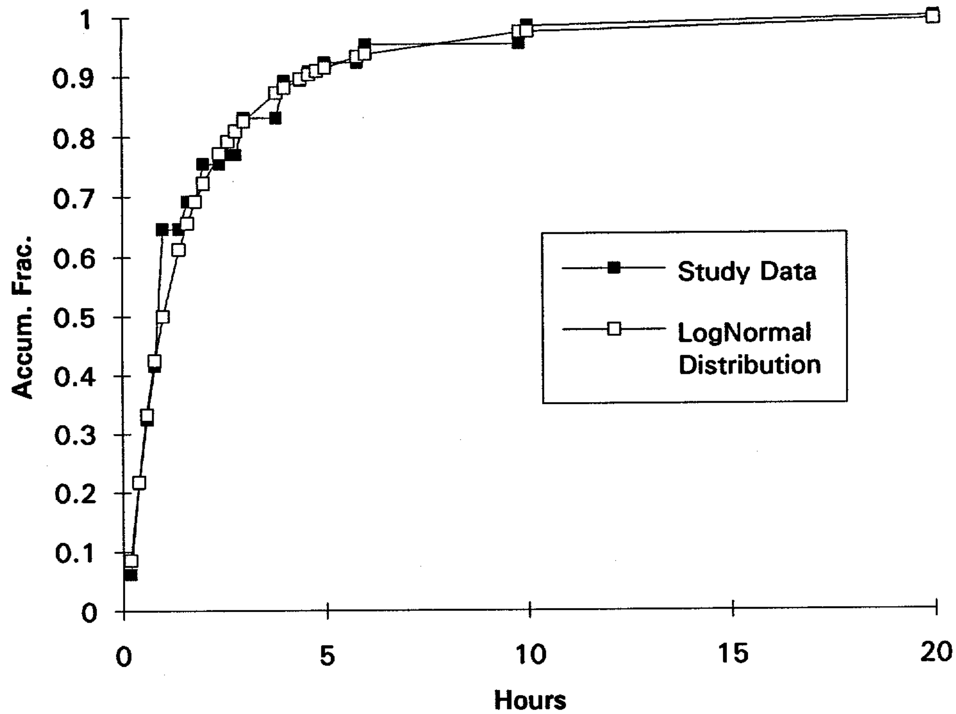

Figure I - Cumulative Histogram of Evacuation Times and Lognormal Distribution