ANL/DIS-00-1

Development of the Table of Initial Isolation and Protective Action Distances for the *2000 Emergency Response Guidebook*

by D.F. Brown, A.J. Policastro, W.E. Dunn,* R.A. Carhart,* M.A. Lazaro,*
W.A. Freeman,* and M. Krumpolc*

Decision and Information Sciences Division
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

October 2000

Work sponsored by U.S. Department of Transportation, Research and Special Programs Administration, Office of Hazardous Materials Technology

---

** Dunn is affiliated with the University of Illinois, Urbana, Illinois; Carhart, Freeman, and Krumpolc are affiliated with the University of Illinois at Chicago; and Lazaro is affiliated with Argonne's Environmental Assessment Division.*

This report is printed on recycled paper.

Contents

Appendixes

Figures

Figures (Cont.)

Figures (Cont.)

Tables

Tables (Cont.)

Notation

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Acronyms and abbreviations used only in tables and figures are defined in the respective tables and figures.

Acronyms and Abbreviations

ABL	atmospheric boundary layer
ACGIH	American Conference of Governmental Industrial Hygienists
AEGL	acute exposure guidance level (National Advisory Committee)
AIHA	American Industrial Hygiene Association
CAS	Chemical Abstracts Services
CASRAM	Chemical Accident Statistical Risk Assessment Model
CBL	convective boundary layer
CFR	*Code of Federal Regulations*
CWI	crosswind-integrated concentration
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EEGL	emergency exposure guidance level (National Research Council)
EEL	Emergency Exposure Level (*AIHA Journal*)
EPA	U.S. Environmental Protection Agency
ERG	Emergency Response Guidebook
ERPG	Emergency Response Planning Guideline (AIHA)
ERPG-1	ERPG Level 1
ERPG-2	ERPG Level 2
ERPG-3	ERPG Level 3
GDP	gross domestic product
GLB	Great Lakes Buoy
HCl	hydrogen chloride
HF	hydrogen fluoride
HMIS	Hazardous Materials Information System
HSE	Health and Safety Executive
IDLH	immediately dangerous to life and health (NIOSH level)
LC_{50}	lethal concentration to 50% of the exposed population; median lethal concentration
LC_{LO}	lowest reported lethal concentration
LOC	level of concern (EPA)
NIOSH	National Institute for Occupational Safety and Health
N_2O_4	nitrogen tetroxide
NOAA	National Oceanic and Atmospheric Administration
n.o.s.	not otherwise specified

OSHA	Occupational Safety and Health Administration
PAD	Protective Action Distance
PEL	permissible exposure limit (OSHA)
RD_{50}	50% decrease in mean respiratory rate
SBL	stratified boundary layer
SEB	surface energy budget
SEBMET	Surface Energy Budget Meteorological (model)
SLOT	specified level of toxicity (HSE)
SO_3	sulfur trioxide
STC	Secretariat of Transport and Communications of Mexico
STEL	short-term exposure limit (ACGIH)
Table	Table of Initial Isolation and Protective Action Distances (in 2000ERG)
TIH	toxic by inhalation
TIHWR	toxic by inhalation by water reactivity
TLV	threshold limit value (ACGIH)
TLV-C	ceiling TLV
TLV-TWA	time-weighted average TLV
UN	United Nations
USGS	U.S. Geological Survey
WQN	Water Quality Network
2000ERG	*2000 Emergency Response Guidebook*

Units of Measure

°C	degree(s) Celsius
cm	centimeter(s)
ft	foot (feet)
g	gram(s)
gal	gallon(s)
h	hour(s)
K	degree(s) Kelvin
kg	kilogram(s)
kPa	kilopascal(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
µm	micrometer(s)
mi	mile(s)
min	minute(s)
mL	milliliter(s)
mmol	millimole(s)
Pa	Pascal(s)
ppm	part(s) per million
s	second(s)

Abstract

This report provides technical documentation for values in the Table of Initial Isolation and Protective Action Distances (PADs) in the *2000 Emergency Response Guidebook* (2000ERG). The objective for choosing the PADs specified in the 2000ERG was to balance the need to adequately protect the public from exposure to potentially harmful substances against the risks and expenses that could result from overreacting to a spill. To quantify this balance, a statistical approach was adopted, whereby the best available information was used to conduct an accident scenario analysis and develop a set of up to 100,000 hypothetical incidents. The set accounted for differences in the types of containers, types of incidents, severities of accidents (i.e., amounts released), locations, times of day, times of year, and meteorological conditions involved. Each scenario was analyzed by using detailed emission rate and atmospheric dispersion models to calculate the downwind chemical concentrations. The safe distance for each incident, defined as the distance downwind from the source at which the chemical concentration falls below the health criteria, was determined. The health criteria used were the American Industrial Hygiene Association's Emergency Response Planning Guideline Level 2 (ERPG-2) or equivalent criteria. The statistical sample of safe distance values for all incidents considered in the analysis was separated into four categories: small spill/daytime release, small spill/nighttime release, large spill/daytime release, and large spill/nighttime release. The 90-percentile safe distance values for each of these groups became the PADs that appear in the 2000ERG table.

Summary

Chemical spills resulting from the transport of toxic materials can pose substantial hazards to the general public and to first responders. To address these hazards, first responders can consult the Emergency Response Guidebook (ERG), which helps them determine whether a spill is potentially hazardous and what actions to take. The year 2000 edition of this guidebook, entitled *2000 Emergency Response Guidebook* (i.e., 2000ERG), was prepared by the U.S. Department of Transportation (DOT), Transport Canada, and the Secretariat of Transport and Communications of Mexico.

The ERG provides information on fire-fighting and mitigation strategies as well as on potential health effects associated with various chemicals, which it lists under their proper shipping names and four-digit United Nations identification numbers. The ERG also provides Initial Isolation Distances and Protective Action Distances (PADs) for a subset of the chemicals it lists: chemicals that are toxic by inhalation (TIH chemicals) and chemicals that react with water to produce TIH gases (TIHWR chemicals). The Initial Isolation Distance identifies the radius of a zone around the release from which all people not directly involved in emergency response are to be kept away. The PAD is the downwind distance from the release that defines a zone in which persons should be either evacuated or sheltered-in-place, depending on the nature of the population at risk (e.g., density, age, health) and the severity of the incident.

This report provides the technical documentation for the values in the 2000ERG Table of Initial Isolation and Protective Action Distances (hereafter referred to as the Table). The objective for choosing the PADs specified in the 2000ERG was to balance the need to adequately protect the public from exposure to potentially harmful substances against the risks and expenses that could result from overreacting to a spill. To quantify this balance, a “level of protection” was defined. The level represents the probability that the listed PAD will allow sufficient protection of the public. A 90% level of protection was selected for the 2000ERG.

Quantitative analysis of the level of protection required a statistical approach to specify the PAD. To achieve this objective, the best available information was used to conduct an accident scenario analysis to develop a set of up to 100,000 hypothetical incidents for each material. The set accounted for differences in the types of containers, types of incidents, severities of accidents (i.e., amounts released), locations, times of day, times of year, and meteorological conditions involved. Each scenario was analyzed by using detailed emission rate and atmospheric dispersion models to calculate the downwind chemical concentrations. The “safe distance” for each incident, defined as the distance downwind from the source at which the chemical concentration falls below the health criteria, was determined. The health criteria used were the American Industrial Hygiene Association’s Emergency Response Planning Guideline Level 2 (ERPG-2) or

equivalent criteria. The ERPG-2 criteria denote the highest chemical concentration at which persons will suffer no irreversible or other serious health effects that could impair their ability to take protective action. The statistical sample of safe distance values for all incidents for each material was separated into four categories: small spill/daytime release, small spill/nighttime release, large spill/daytime release, and large spill/nighttime release. The 90-percentile safe distance values for each of these groups became the PADs that appear in the Table.

Several changes from earlier versions of the Table were made to produce the Table that appears in the 2000ERG. Specific improvements and changes are listed below, and their influences on PADs are discussed.

1. The methodology for modeling TIHWR releases was substantially improved, allowing them to be treated at the same level of detail as land-based TIH releases. As a result, in the 2000ERG, water-reactive materials are listed together with TIH materials in the Table. A key factor in developing this methodology was an experimental program that provided important reaction data on 21 candidate materials. As a result of the experiments and detailed literature reviews, 36 new materials were added to the TIHWR list, which had contained 37 materials in the 1996 edition of the ERG. In addition, 3 of the 37 materials on the old list were removed. Thus, the number of TIHWR materials in the 2000ERG list totals 70.

2. Twenty chemicals recognized as chemical warfare agents were added to the Table for cases in which they would be used as a weapon, since release scenarios for weapons-related incidents are very different from release scenarios for transportation-related TIH incidents. Ten of the 20 new chemicals also met the criteria for being TIH chemicals, so they were also entered in the Table for cases in which they would be released in transportation-related incidents. In addition, new entries for several other industrial chemicals already on the TIH list (e.g., hydrocyanic acid, phosgene) were created for cases in which they would be used as a weapon.

3. Shipment profiles were developed for each TIH chemical so the types of containers and transport modes (e.g., rail, highway) used to ship the chemicals would be more closely reflected. The shipment profiles specified the bulk and package freight containers typically used to transport the material, as well as the relative frequency at which each type of container is involved in incidents. Using shipment profiles resulted in some substantial changes in PADs. For many chemicals, the PADs for small spills became shorter than they were in the two previous editions of the ERG because the estimates for those releases were less conservative. However, since the shipment profiles provided a more realistic split between rail and highway transportation than had been considered before, the PADs for large spills of some liquefied gases became somewhat longer than they were in the 1996 ERG.

4. The database on chemical properties that is used for calculating emission rates was substantially updated. Improved techniques were used to estimate some properties that had not been known or were crudely approximated in earlier versions of the ERG. This effort resulted in large changes for some chemicals but no changes for chemicals that had been well characterized in past ERGs (chlorine, ammonia, sulfur dioxide, etc.).

5. A dense gas dispersion algorithm was added to CASRAM, the risk assessment model used to determine Initial Isolation Distances and PADs. The special consideration of dense gas effects did not greatly influence the final PADs, except for the PADs for liquefied gases with low to moderate toxicity. For this class of materials, inclusion of dense gas effects shortened PADs by up to 15%.

6. Accidents in Canada and Mexico, in addition to those in the United States, were considered in the statistical release and dispersion analysis. The inclusion of these accidents had a relatively small impact on the PADs because (1) most accidents (89%) occur in the United States and (2) the effects of meteorological conditions (chiefly temperature) in Canada and Mexico tended to offset each other.