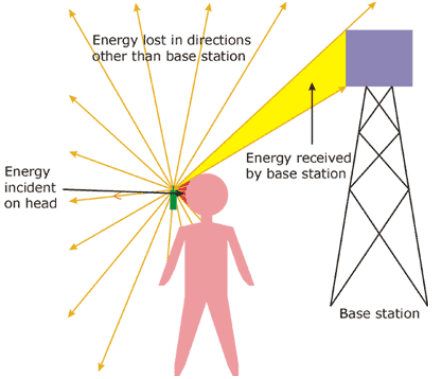
The Nature of the Accident Process

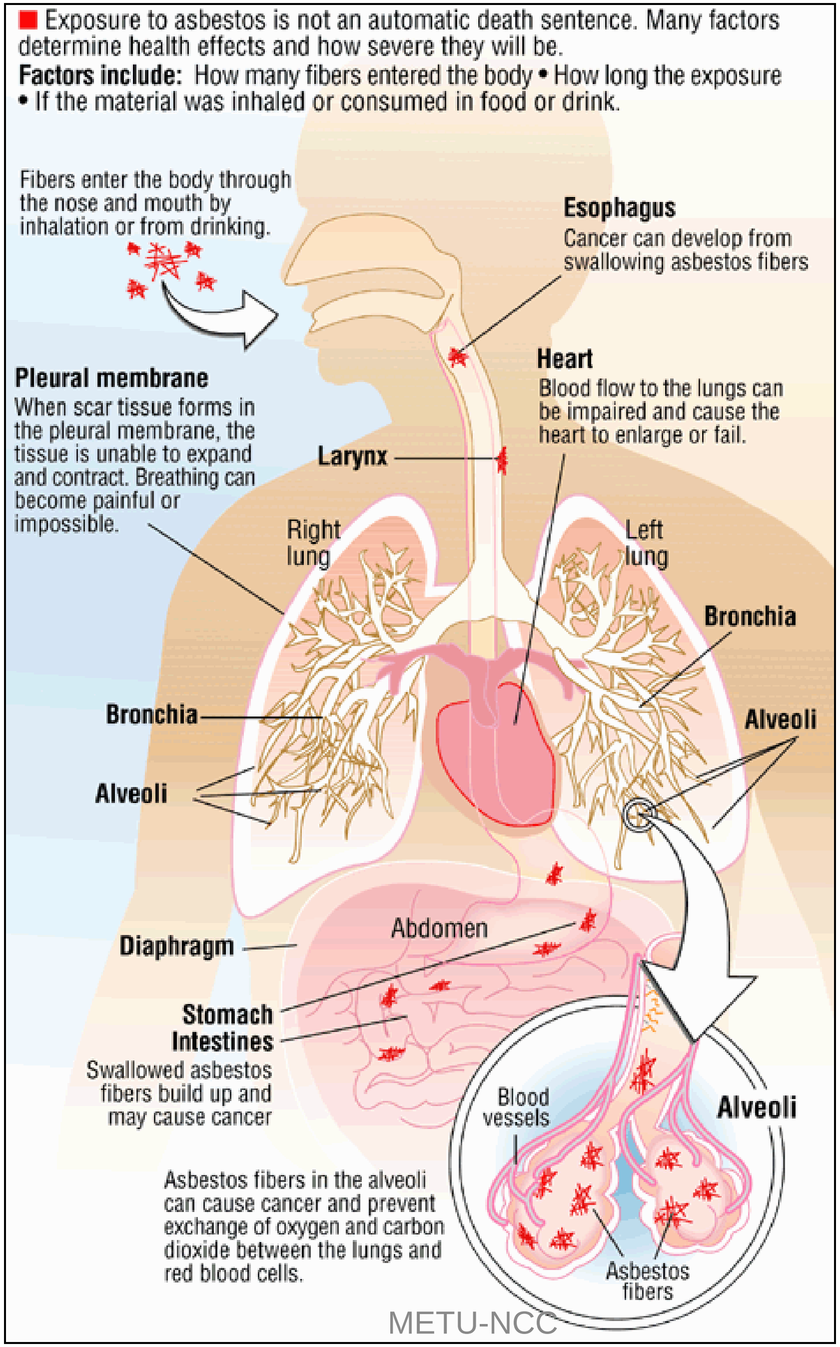
Type of Accident	Probability of occurrence	Potential for fatality	Potential for economic loss
Fire	High	Low	Inter-mediate
Explosion	Inter-mediate	Inter-mediate	High
Toxic release	Low	High	Low

2. Toxicology

Toxins

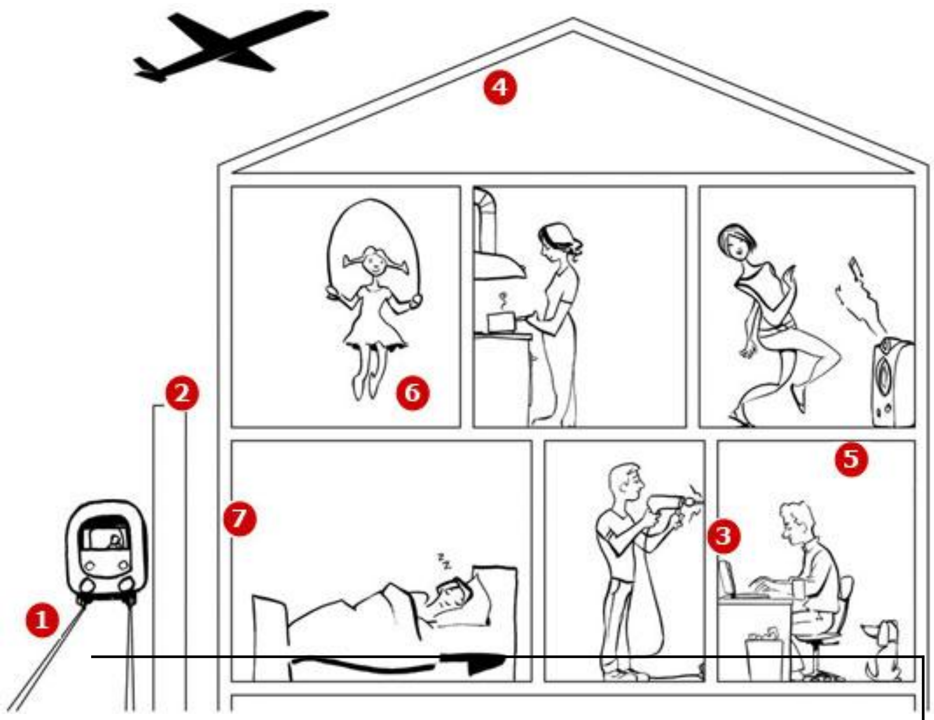
- *Toxicology*: interaction of people with chemical or physical agents
- Chemicals and physical agents are potential toxins
- Dusts, fibers, noise, radiation
- *Industrial hygiene*: methods to prevent or reduce intrusion of toxicants



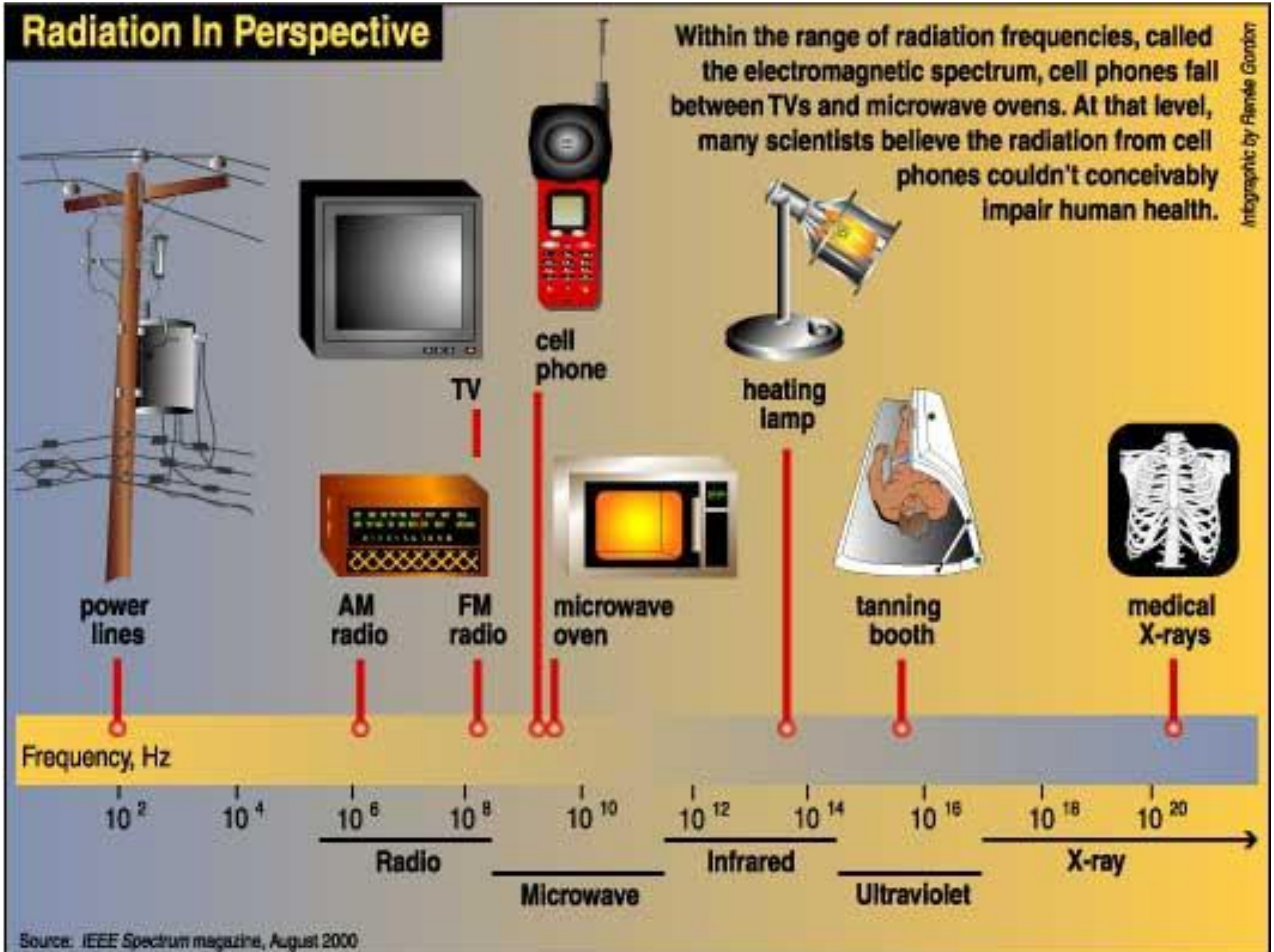

Exposure to asbestos is not an automatic death sentence. Many factors determine health effects and how severe they will be.
Factors include: How many fibers entered the body • How long the exposure • If the material was inhaled or consumed in food or drink.
Fibers enter the body through the nose and mouth by inhalation or from drinking.
Esophagus
Cancer can develop from swallowing asbestos fibers
Heart
Blood flow to the lungs can be impaired and cause the heart to enlarge or fail.
Pleural membrane
When scar tissue forms in the pleural membrane, the tissue is unable to expand and contract. Breathing can become painful or impossible.
Larynx
Right lung
Left lung
Bronchia
Alveoli
Bronchia
Alveoli
Abdomen
Diaphragm
Stomach
Intestines
Swallowed asbestos fibers build up and may cause cancer
Blood vessels
Alveoli
Asbestos fibers in the alveoli can cause cancer and prevent exchange of oxygen and carbon dioxide between the lungs and red blood cells.
Asbestos fibers

- **Library - 35 dB**
- **Office - 60- 65**
- **Normal traffic noise 70 - 80 dB**
- **Airport (plane take off) - 120 dB**
  - **No damage below 80 dB**

$$dB = 10\log\frac{I}{I_0}\ (I_0 = 1\times10^{-12}\,W/m^2)$$



Source of Sound/Noise	Approximate Sound Pressure in µPa
Launching of the Space Shuttle	2,000,000,000
Full Symphony Orchestra	2,000,000
Diesel Freight Train at High Speed at 25 m	200,000
Normal Conversation	20,000
Soft Whispering at 2 m in Library	2,000
Unoccupied Broadcast Studio	200
Softest Sound Human can Hear	20

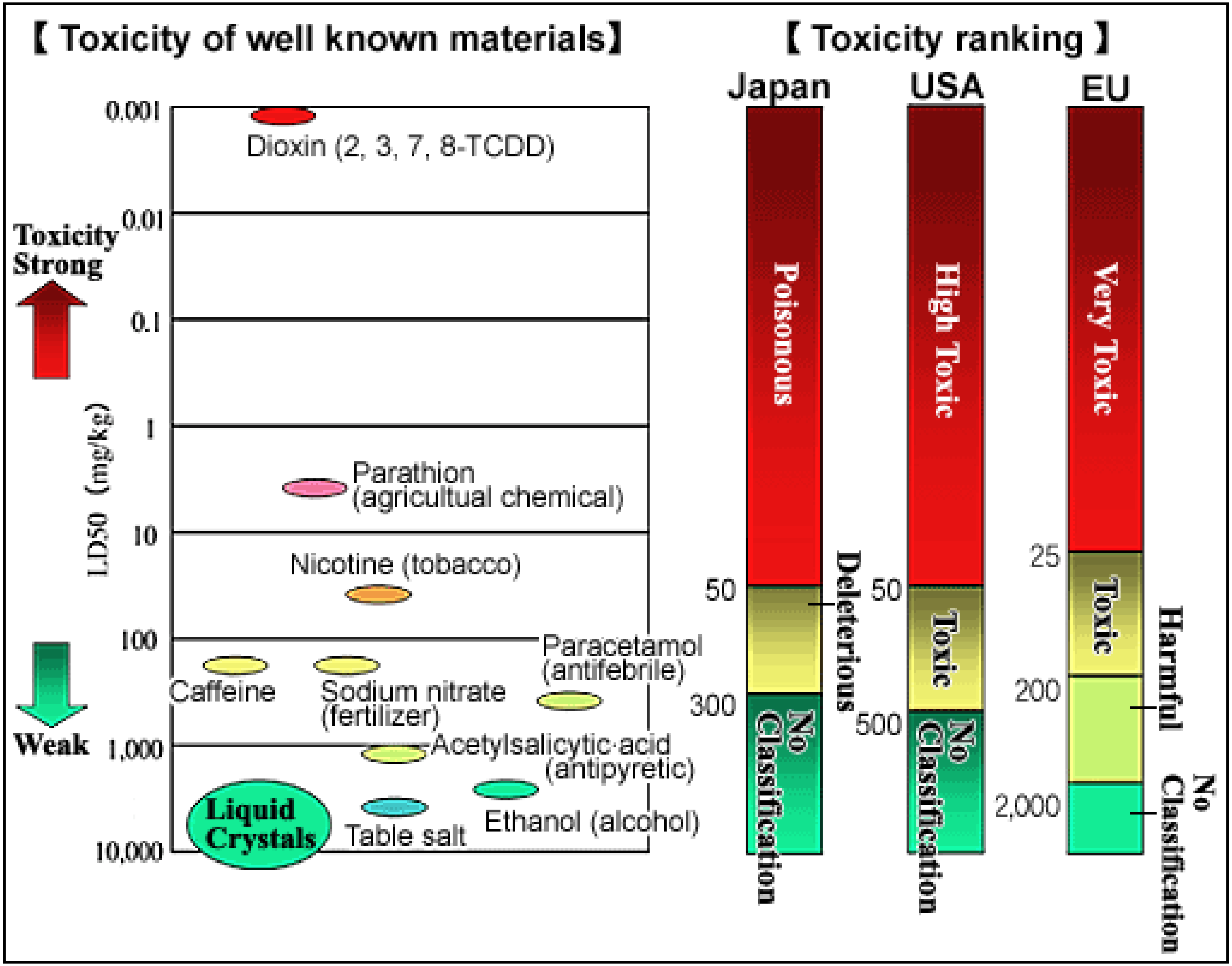

Radiation In Perspective
Within the range of radiation frequencies, called the electromagnetic spectrum, cell phones fall between TVs and microwave ovens. At that level, many scientists believe the radiation from cell phones couldn't conceivably impair human health.
Infographic by Renée Gordon
cell phone
TV
heating lamp
power lines
AM radio
FM radio
microwave oven
tanning booth
medical X-rays
Frequency, Hz
10 2
10 4
10 6
10 8
10 10
10 12
10 14
10 16
10 18
10 20
Radio
Microwave
Infrared
Ultraviolet
X-ray
Source: IEEE Spectrum magazine, August 2000

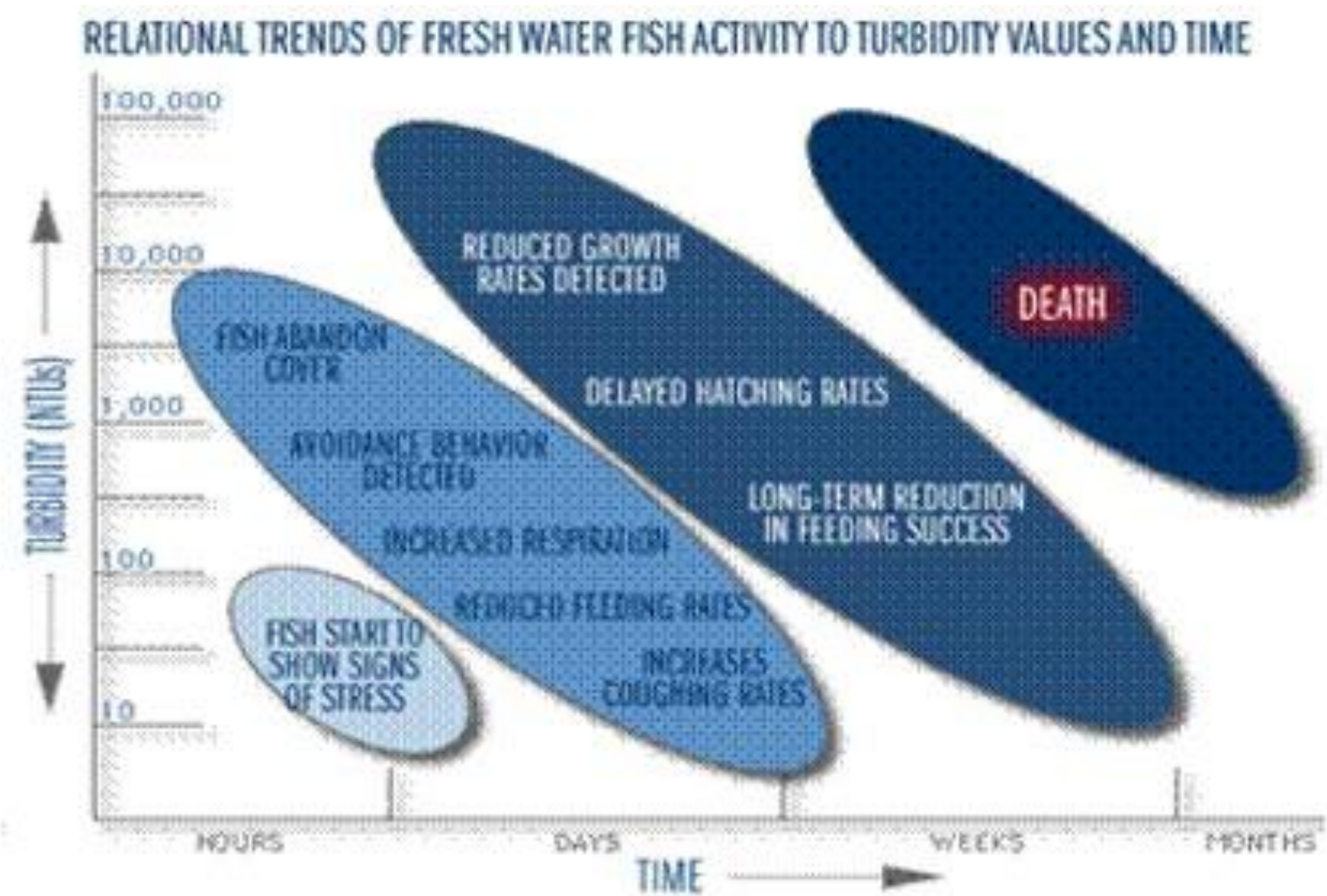
Toxic Chemicals

- What makes a chemical a toxin?
- Amount or dose is a factor
  - Medicines and water, both beneficial in proper amounts, can be harmful.
  - There are no harmless substances, only harmless ways of using substances
  - 32 year old man died after drinking too much water [2005, Liverpool England]
  - Water washed the essential salts from his body and caused his brain to swell and he fell into a coma before he died.

Toxicity

- ***Toxicity*: an intrinsic property of an agent that causes an effect on a person**
- ***Toxic hazard*: magnitude of effect on a person ☞ can be reduce by *hygiene***
- ***Acute toxicity:* short period exposure**
- ***Chronic toxicity:* multiple exposure long period exposure**


【Toxicity of well known materials】
【Toxicity ranking】
Japan
USA
EU
0.001
0.01
0.1
1
10
100
1,000
10,000
LD50 (mg/kg)
Toxicity Strong
Weak
Dioxin (2, 3, 7, 8-TCDD)
Parathion (agricultual chemical)
Nicotine (tobacco)
Paracetamol (antifebrile)
Caffeine
Sodium nitrate (fertilizer)
Acetylsalicytic acid (antipyretic)
Liquid Crystals
Table salt
Ethanol (alcohol)
Poisonous
Deleterious
No Classification
50
300
High Toxic
Toxic
No Classification
50
500
Very Toxic
Toxic
Harmful
No Classification
25
200
2,000


RELATIONAL TRENDS OF FRESH WATER FISH ACTIVITY TO TURBIDITY VALUES AND TIME
100,000
10,000
1,000
100
10
TURBIDITY (NTUs)
REDUCED GROWTH RATES DETECTED
DEATH
FISH ABANDON COVER
DELAYED HATCHING RATES
AVOIDANCE BEHAVIOR DETECTED
LONG-TERM REDUCTION IN FEEDING SUCCESS
INCREASED RESPIRATION
REDUCED FEEDING RATES
FISH START TO SHOW SIGNS OF STRESS
INCREASES COUGHING RATES
HOURS
DAYS
WEEKS
MONTHS
TIME

Infusion of Toxins

- **Inhalation: airborne concentrations can reduce the transfer of gases.**
- **Hazardous particulates: 2 - 5 μm can reach the bronchial tubes and alveoli.**
- **Absorption, skin: rate varies widely with various chemicals**
- **Injection: highest blood concentrations**
- **Ingestion through contamination**

Table 2-1 Entry Routes for Toxicants and Methods for Control

Entry route	Entry organ	Method for control
Ingestion	Mouth or stomach	Enforcement of rules on eating, drinking, and smoking
Inhalation	Mouth or nose	Ventilation, respirators, hoods, and other personal protection equipment
Injection	Cuts in skin	Proper protective clothing
Dermal absorption	Skin	Proper protective clothing

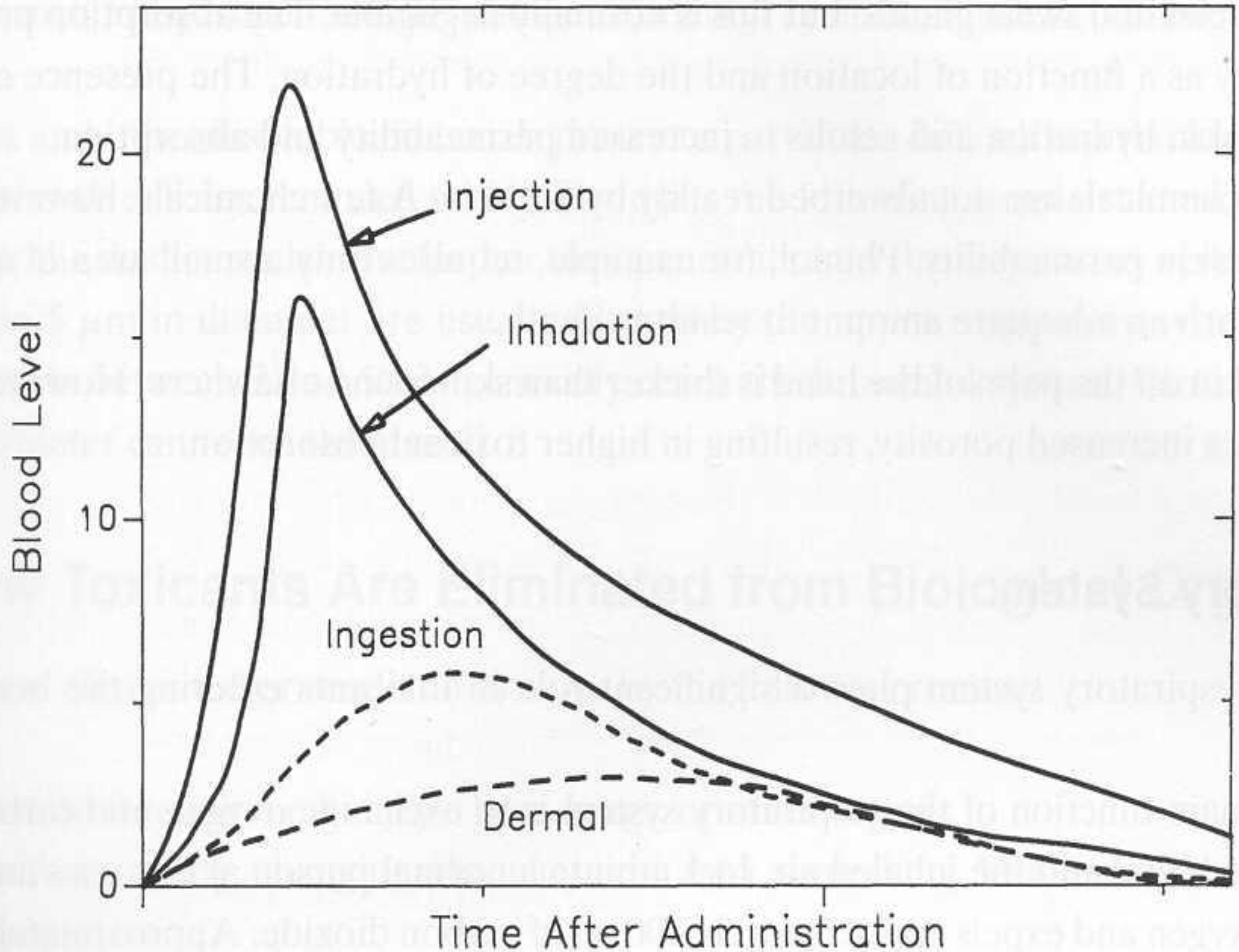


Figure 2-1 Toxic blood level concentration as a function of route of exposure. Wide variations are expected as a result of rate and extent of absorption, distribution, biotransformation, and excretion.

Elimination of Toxins

- Excretion: kidneys, liver, lungs
- Detoxification: digestive tract
- Storage: fat cells
- High infusion: damage to kidneys, liver, lungs therefore reducing elimination.

Comparative Physiology

Just another WordPress.com weblog

HOME ABOUT THE COMPARATIVE PHYSIOLOGY BLOG

← Blubber in Warm Water *PAPER CHANGED!* →

Fat Cells Are The Most Effective Toxin Store

Posted on February 12, 2010 | 1 Comment

Because we have spent the last few million years as tropical primates, where nutrients are super abundant and a lack thereof just does not happen, we have not used the energy-storing capacity of our fat reserves, for a very long time. We have to trace our lineage back out of the forests and into the temperate zones once again where we are closer to bears than monkeys – that is the last time our inherent fat mechanism was used to store foodstuff to sustain the long, desert-like winters.

SEARCH IT!

Search

RECENT ENTRIES

- Thanks everybody
- Mutation of Hemoglobin: Sickle Cell
- Oxygen Transport in Review
- hemoglobin animation
- Desert Animals Partial Recap
- Amazing close up video of Hummingbird @ feeder

Toxicological Studies

- Toxicant
  - Must be identified with respect to its composition and its physical state
- The target or test organism
  - From a simple single cell up through the higher animals
- The effect or response to be monitored
- The dose range
  - Depend on the method of delivery
  - Milligrams of agent per kilogram of body weight(*mg/kg*, ingestion, injection)
  - Milligram of agent per cubic meter of air or millions of particles per cubic foot (mg/m^3, *mppcf*)
- The period of the test
  - Depend on whether long- or short-term effects

Single Exposure Dose-Response

- **Wide levels of response to toxins with numbers affected at each dose level, Crowl, Fig. 2-5, p. 45.**
- **Responses of a large number of people follow a normal (Gaussian) distribution, Fig. 2-2, p. 42**

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

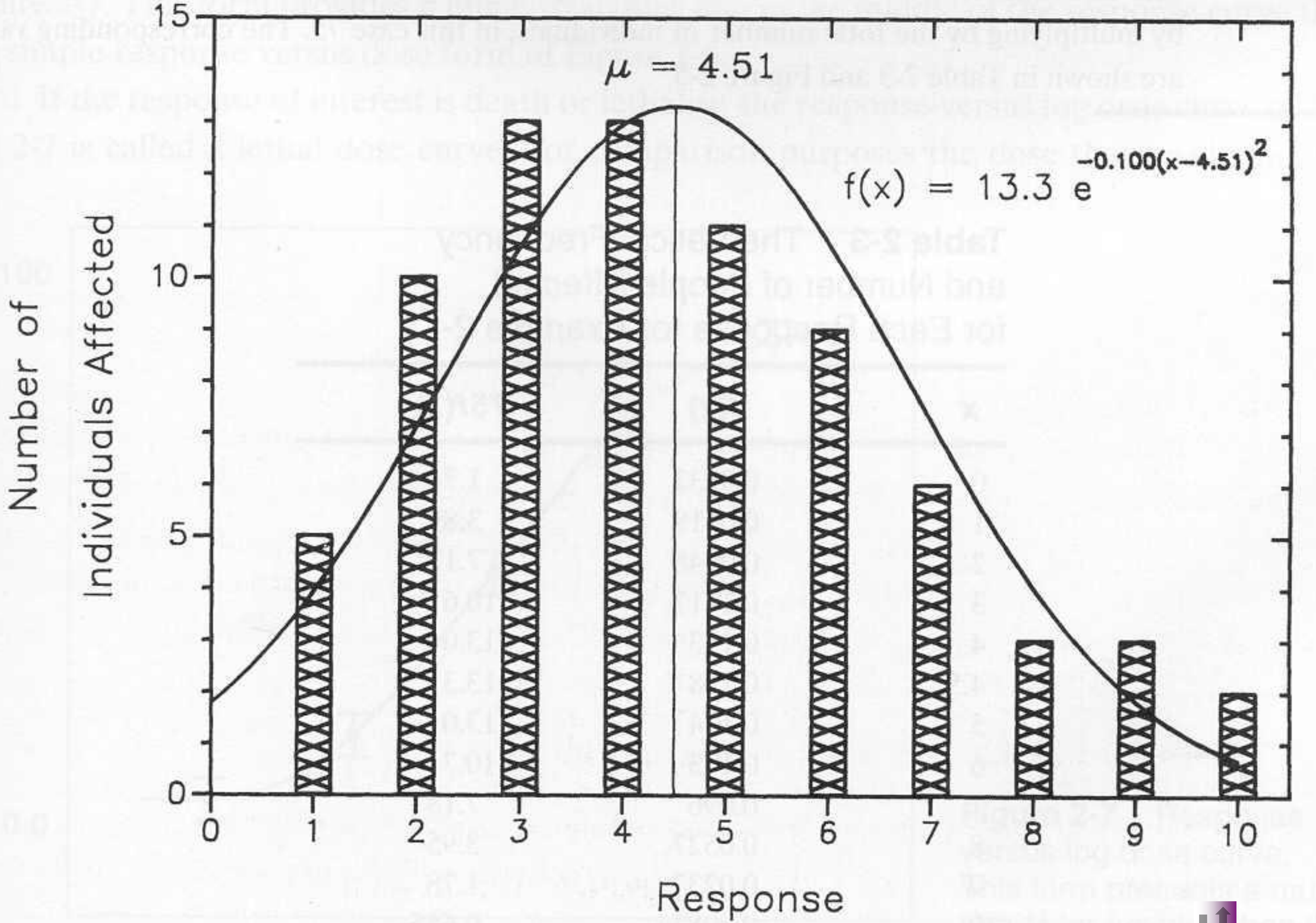
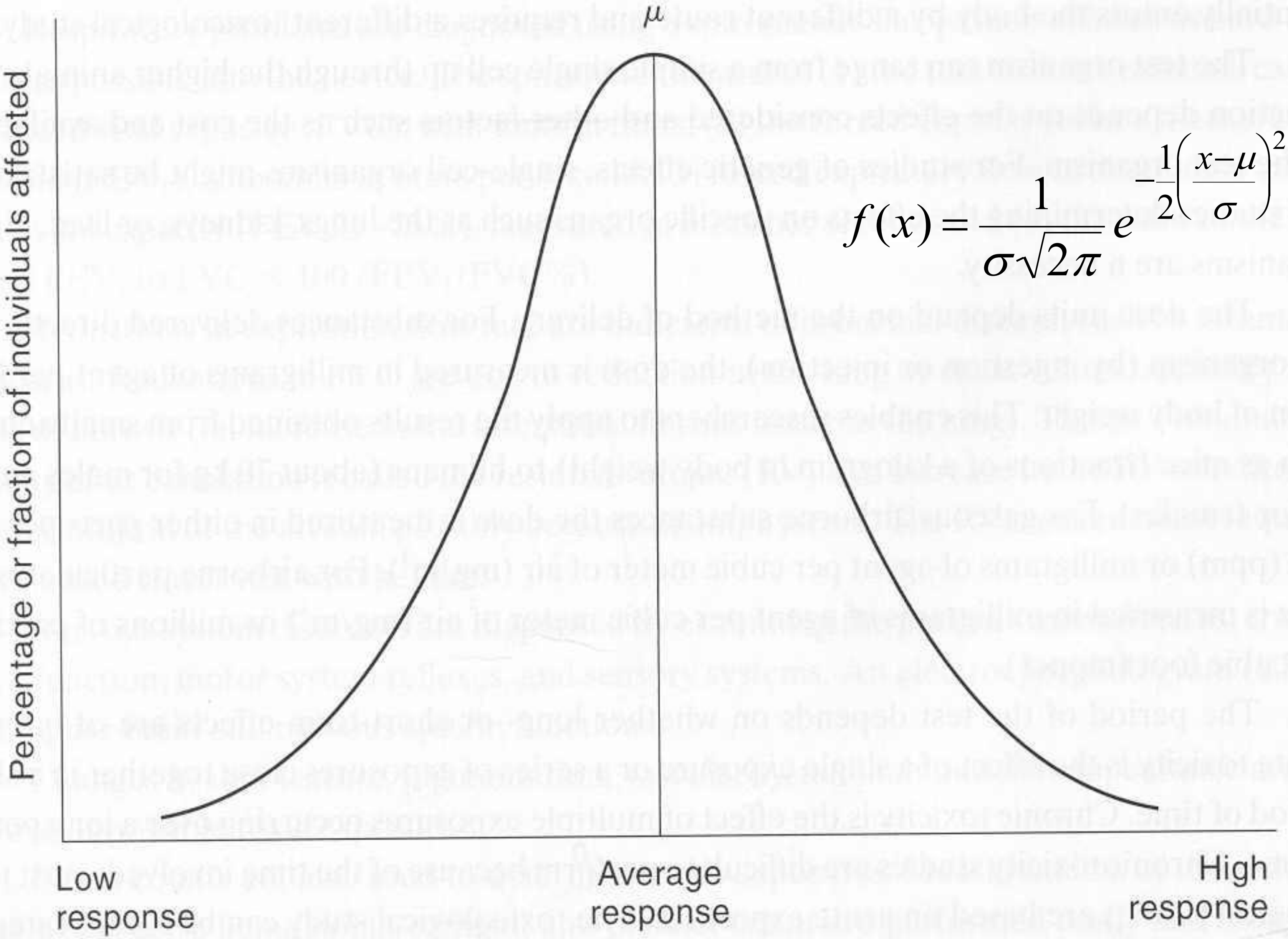


Figure 2-5 Percentage of individuals affected based on response.



$$f(x)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Figure 2-2 A Gaussian or normal distribution representing the biological response to exposure to a toxicant.

Normal Distribution

- $f(x)$: fraction of individuals with a specific response level
- x: response
- μ: mean of the response (curve position)
- σ : standard deviation of the response (curve shape); 1σ, 68%; 2σ, 95.5%
- Number of individuals affected with a specific response = $f(x)N$

where N = total number

- **Standard deviation and mean characterize the shape and the location of the normal distribution curve**

Mean

$$\mu = \frac{\sum_{i=1}^{n} x_i f(x_i)}{\sum_{i=1}^{n} f(x_i)}$$

Variance

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \mu)^2 f(x_i)}{\sum_{i=1}^{n} f(x_i)}$$

N is the number of data points

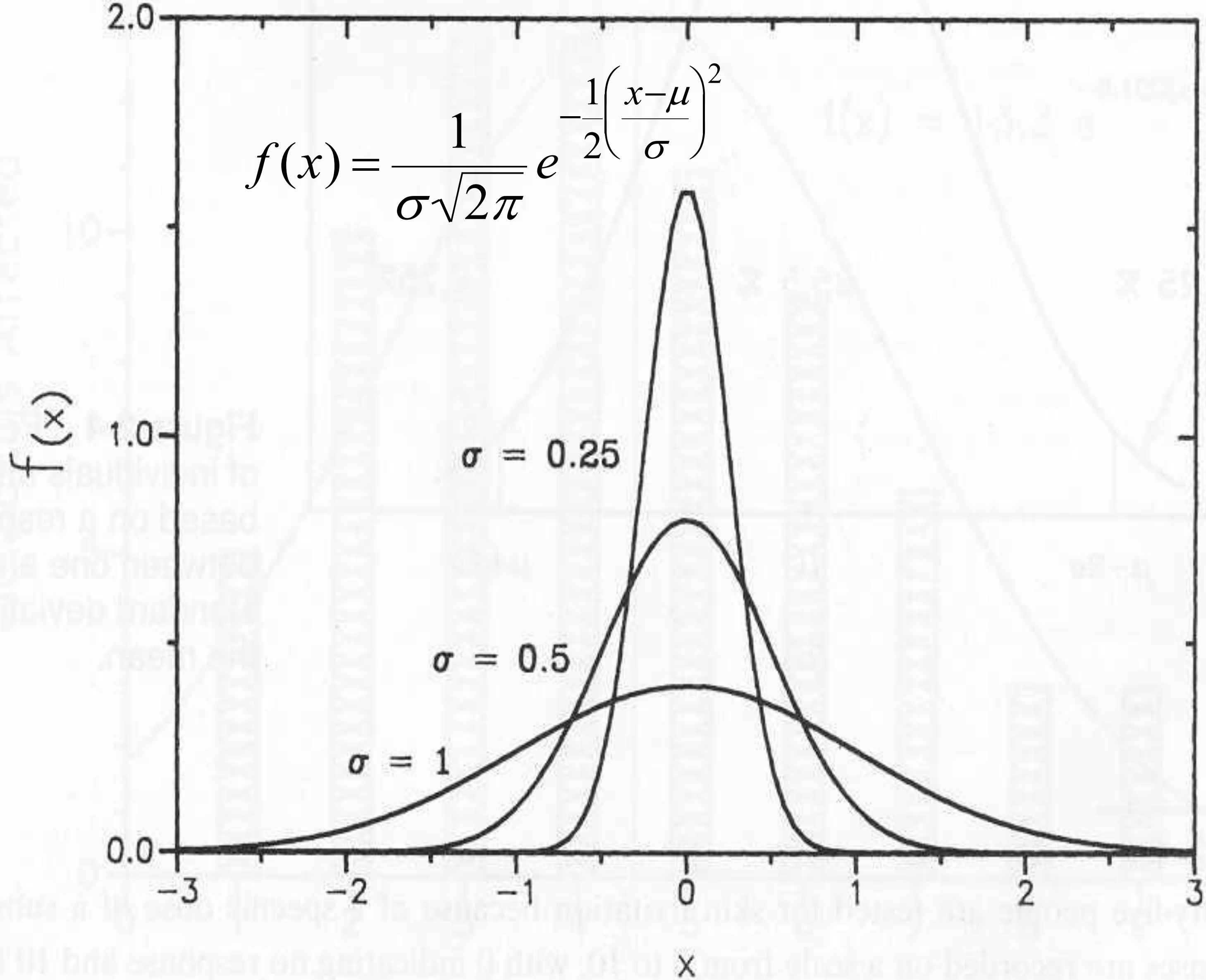


Figure 2-3 Effect of the standard deviation on a normal distribution with a mean of 0. The distribution becomes more pronounced around the mean as the standard deviation decreases.

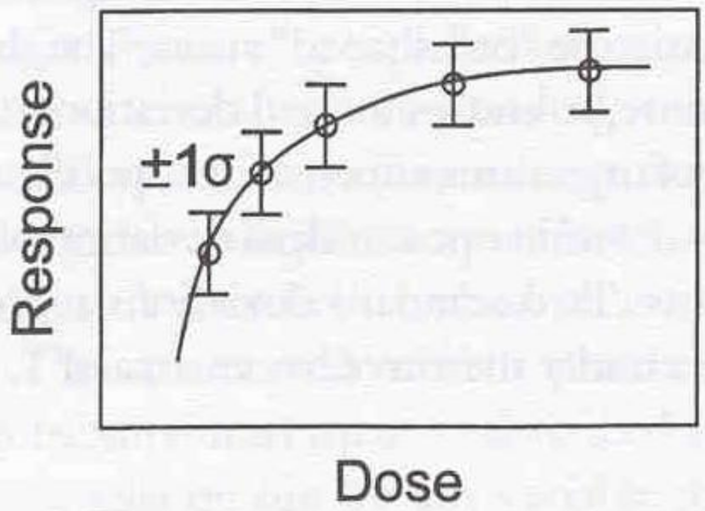


FIGURE 2.86. Typical dose–response curve.

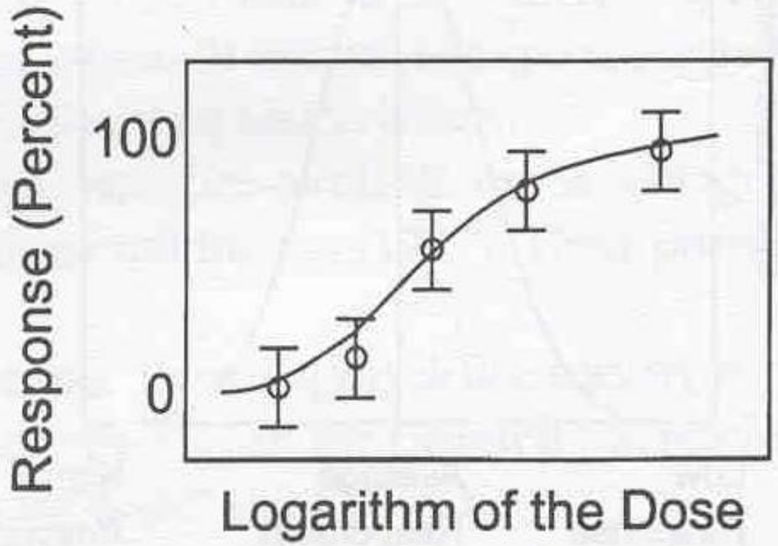
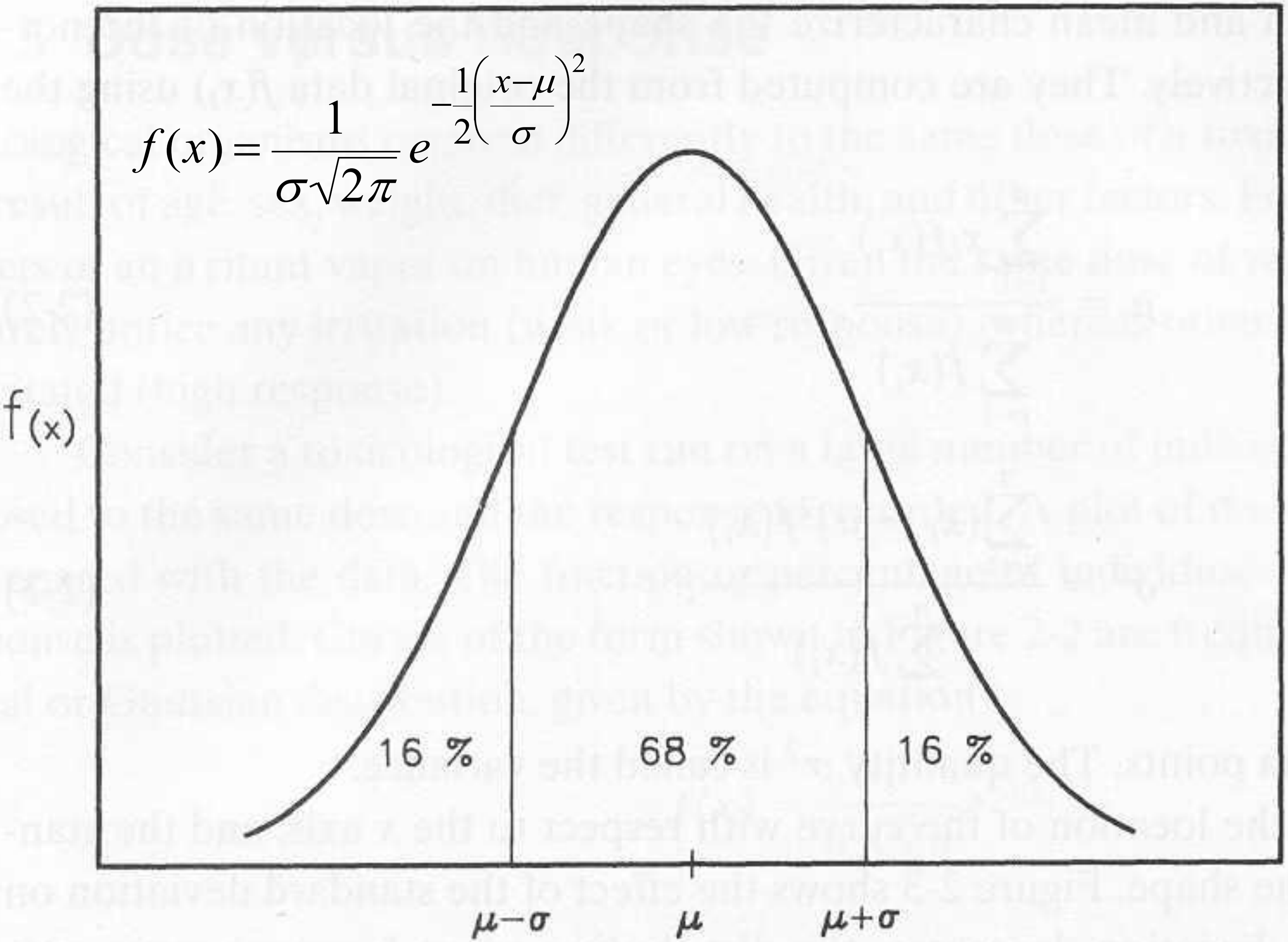


FIGURE 2.87. Typical response versus log(dose) curve.

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$



(a)

$$f(x)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

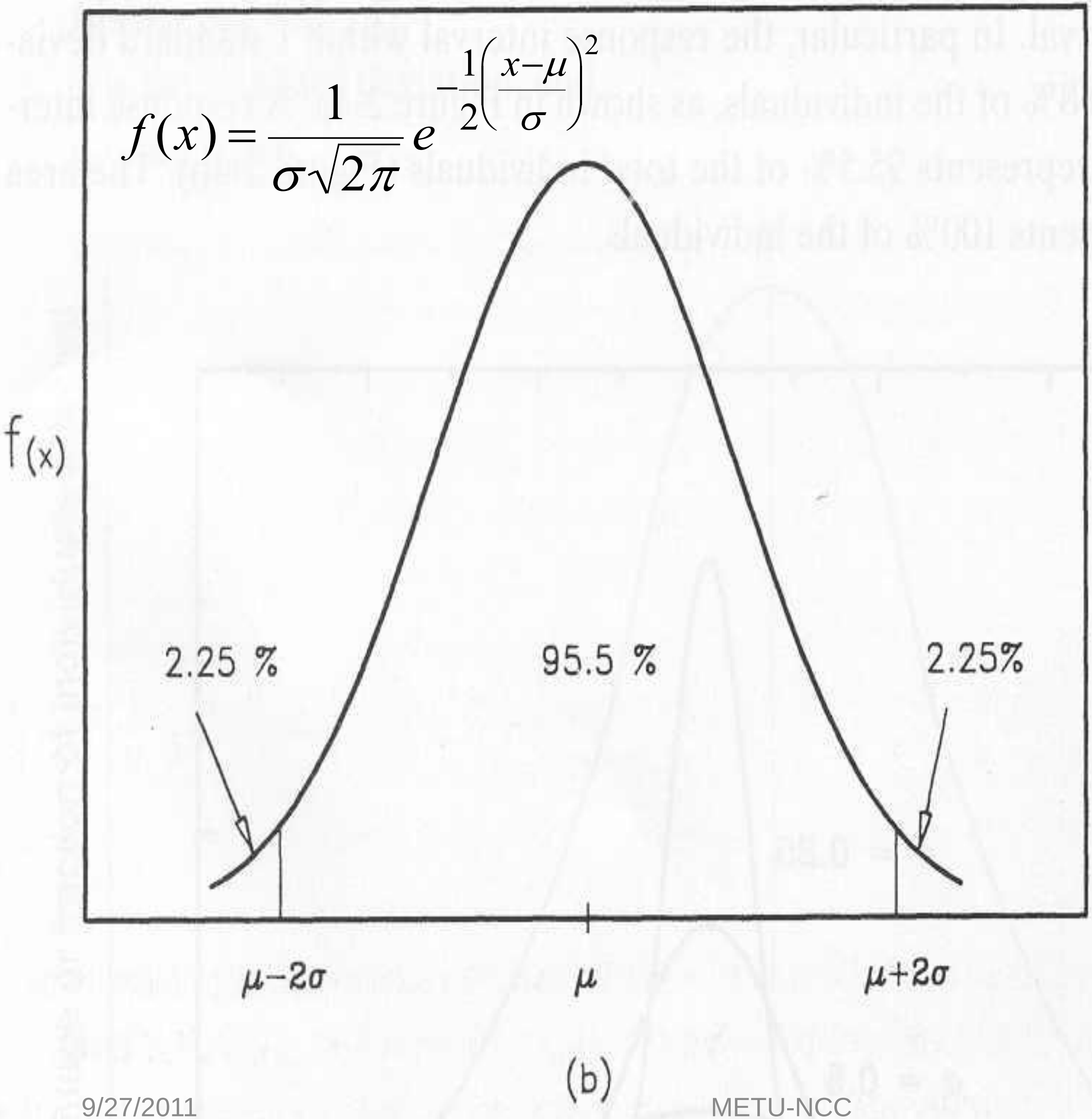


Figure 2-4 Percentage of individuals affected based on a response between one and two standard deviations of the mean.

- **Example 2-1**
  - **75 people**
  - **tested for skin irritation**
  - **the responses are recorded on a scale from 0 to 10, with 0 indicating no response and 10 indicating a high response**
  - **The number of individual response is given in the following table**
    - **A. plot a histogram of the number of individuals affected versus the response**
    - **Determine the mean and the standard deviation**
    - **Plot the normal distribution on the histogram of the original data**

Response	Number of individuals affected
0	0
1	5
2	10
3	13
4	13
5	11
6	9
7	6
8	3
9	3
10	2
	75

Table 2-3 Theoretical Frequency and Number of People Affected for Each Response for Example 2-1

x	$f(x)$	$75f(x)$
0	0.0232	1.74
1	0.0519	3.89
2	0.0948	7.11
3	0.1417	10.6
4	0.173	13.0
4.51	0.178	13.3
5	0.174	13.0
6	0.143	10.7
7	0.096	7.18
8	0.0527	3.95
9	0.0237	1.78
10	0.00874	0.655

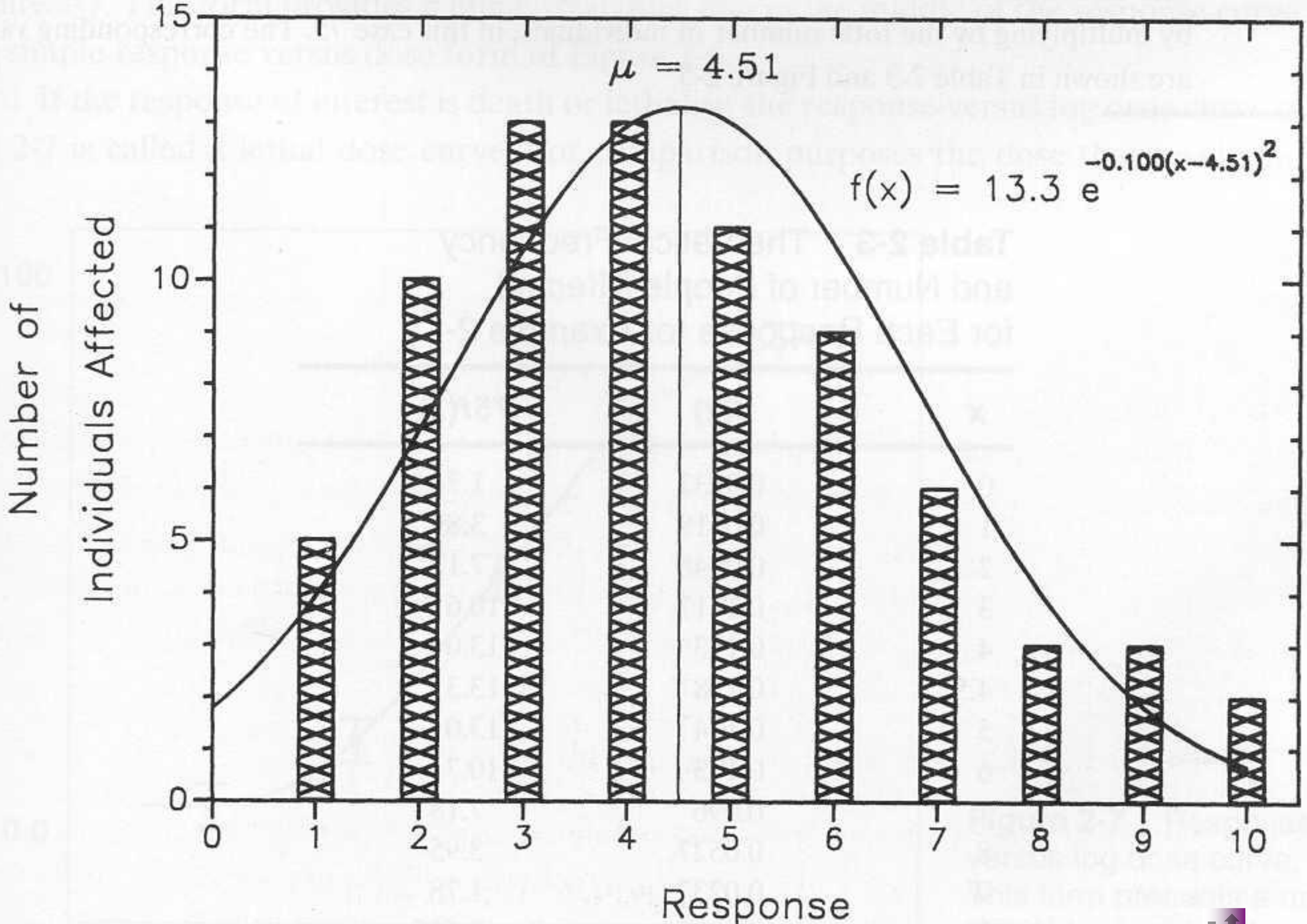


Figure 2-5 Percentage of individuals affected based on response.

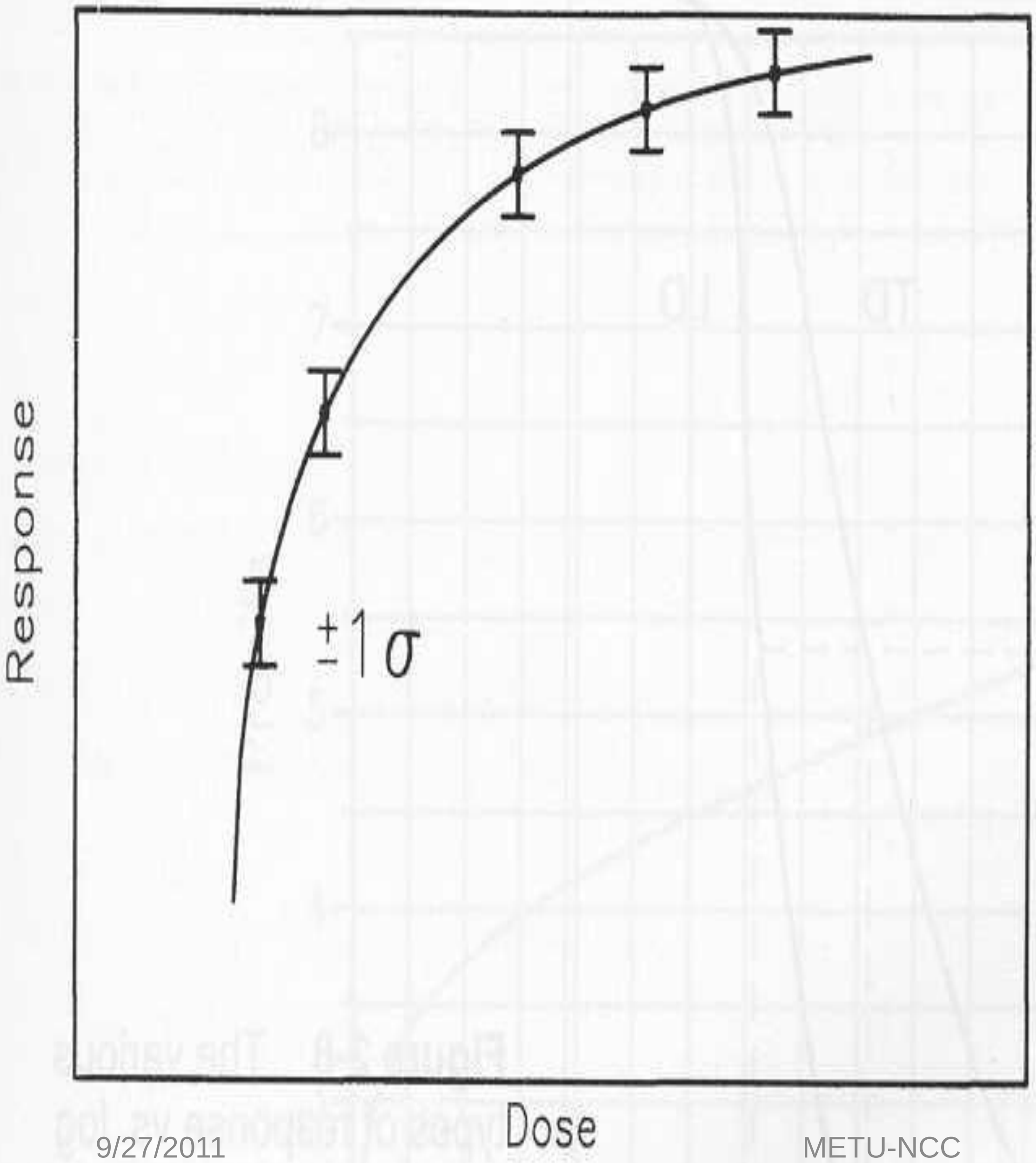


Figure 2-6 Dose-response curve. The bars around the data points represent the standard deviation in response to a specific dose.

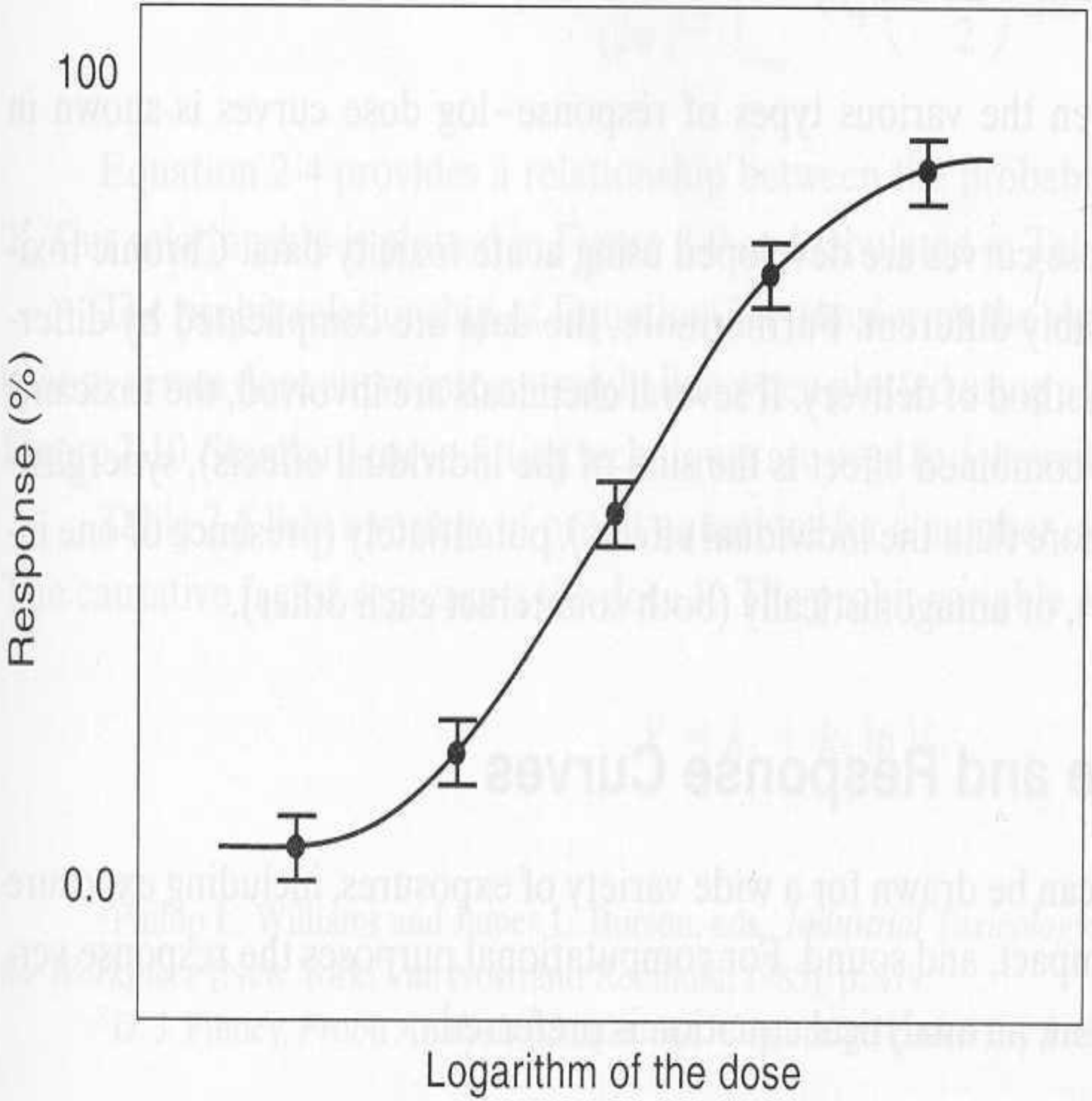


Figure 2-7 Response versus log dose curve. This form presents a much straighter function than the one shown in Figure 2-6.

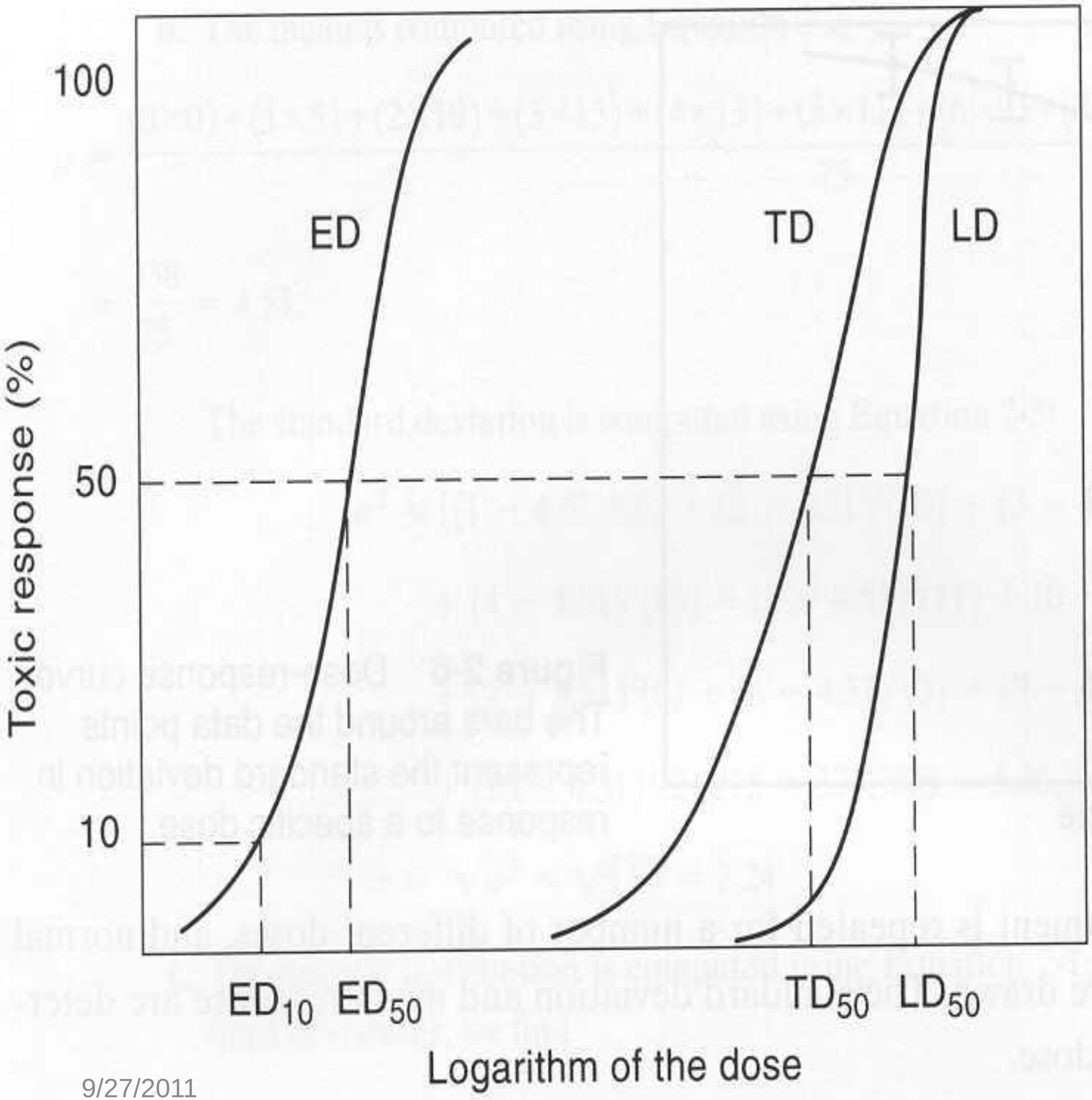


Figure 2-8 The various types of response vs. log dose curves. ED, effective dose; TD, toxic dose; LD, lethal dose. For gases, LC (lethal concentration) is used.

Multiple Exposure Dose-Response

- A distribution curve for each dose level represents the response levels for that dose
- Construct a dose-response curve from mean responses for all doses (Figs. 2-6, 2-7 p. 47) Show $\pm 1\sigma$ or 68% of responses
- LD (lethal dose) curve with LD_{50} dose lethal for 50% of individuals, Fig. 2-8, p. 48
- ED (effective dose): reversible effect
- TD (toxic dose): irreversible damage

Multiple Exposures

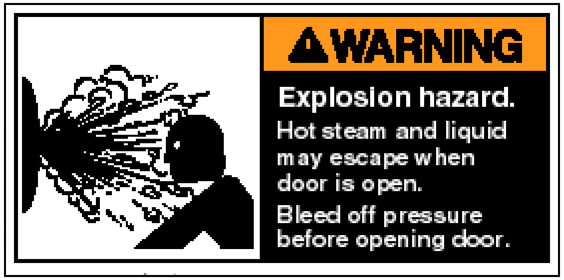
- Exposures from > 1 toxin of same class
- Exposures from > 1 toxin of different classes: response not additive
- Synergistic response: effect more than sum of individual effects

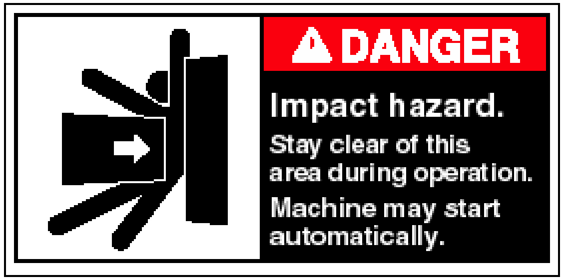
Consequence Predictions

- **Estimate effects of toxins, fires, explosions**
- **Extend limited dose-response and other consequence data to causes or cause levels for which affects have not been measured**
- **Consequences needed to assess or estimate** ***risk = (consequence)•(likelihood)***

Models for Dose and Response Curves

- Response versus dose curve
  - Can be drawn for a wide variety of exposures, including exposure to heat, pressure, radiation, impact and sound





Probit Equation

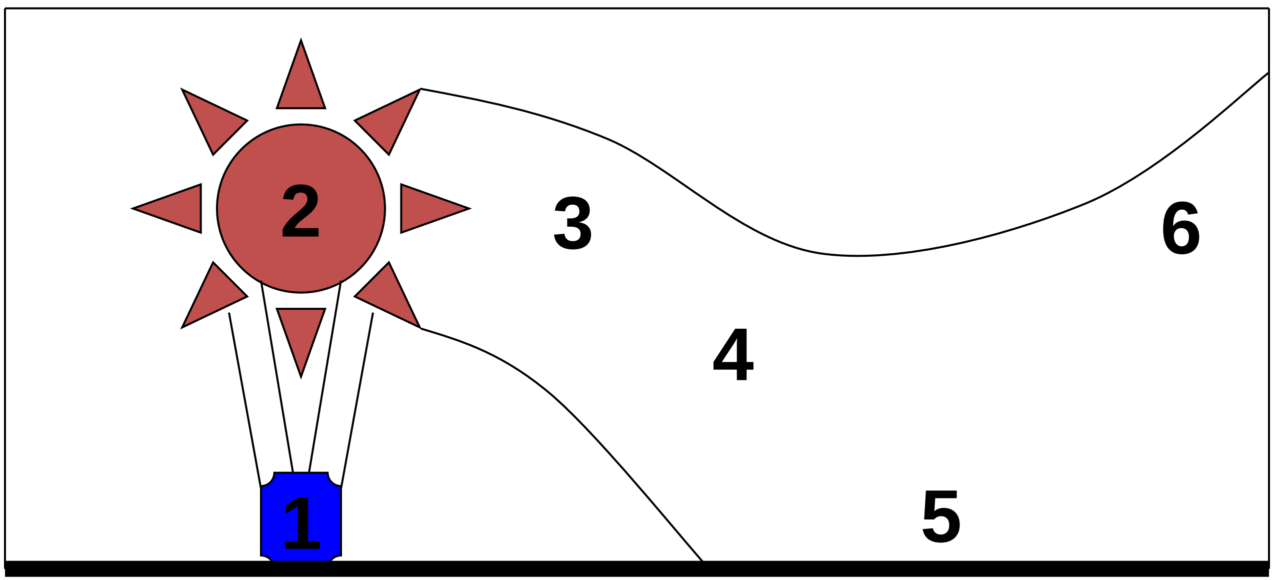
- **Form:** $\mathbf{Y = k_1 + k_2\, \mathit{ln} V}$**, V = dose level**
- **Method: Calculate Y and convert to %**
- **Note: yields *average* % of affected individuals or *average* consequence**
- ***Probit* parameters ($\mathbf{k_1, k_2}$) and causative variables for a variety of exposures V are in Tab. 2-5, p. 51.**

Predict Consequence of Exposure to Effect

- The average response or % affected vs. the *ln* of the dose or cause yields a similar sigmoid curve for all causes.
- Transform curve to the straight line of *Probit* vs. *ln* of the dose
- Convert *Probit* to % individuals affected
- Result: represent a variety of events in a linear form to predict the result of a causative variable, e.g., concentration, time, pressure, impulse, radiation intensity

Example: Exposure to release of gases heavier than air

Predict effects of exposure near the surface.



Stages

1. Source
2. Acceleration, Diffusion
3. Gravity
4. Transition
5. Surface
6. Turbulence

Predict % affected by the exposure.

Probit Method: Single Exposures

- **To predict % affected from toxins, convert dose-curve to an equation**
- **Use the normal distribution function, *f(x)*, to represent the dose-response data**
- **Let $u = (x-\mu)/\sigma$**

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} = \frac{1}{\sqrt{2\pi}} e^{-\left(\frac{u^2}{2}\right)}$$

Probit Method

- **Y is the *Probit* variable to determine probability or % of individuals affected**

- **Probability, % =** $$\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y-5}\exp\left(-\frac{u^2}{2}\right)du$$

- **On a linear *Probit* scale, the sigmoidal dose-response curve is converted to a straight line (Fig. 2-10, p. 50)**

Probit Method

- Y ranges from 2 to 8 in units of s.

Y	Y- 5	Probability, %	
2	- 3	0	
3	- 2	2	
4	- 1	16	
5	0	50	$x = \mu$ (mean)
6	1	84	
7	2	98	
8	3	100	

Table 2-4 Transformation from Percentages to Probits[1]

%	0	1	2	3	4	5	6	7	8	9
0	–	2.67	2.95	3.12	3.25	3.36	3.45	3.52	3.59	3.66
10	3.72	3.77	3.82	3.87	3.92	3.96	4.01	4.05	4.08	4.12
20	4.16	4.19	4.23	4.26	4.29	4.33	4.36	4.39	4.42	4.45
30	4.48	4.50	4.53	4.56	4.59	4.61	4.64	4.67	4.69	4.72
40	4.75	4.77	4.80	4.82	4.85	4.87	4.90	4.92	4.95	4.97
50	5.00	5.03	5.05	5.08	5.10	5.13	5.15	5.18	5.20	5.23
60	5.25	5.28	5.31	5.33	5.36	5.39	5.41	5.44	5.47	5.50
70	5.52	5.55	5.58	5.61	5.64	5.67	5.71	5.74	5.77	5.81
80	5.84	5.88	5.92	5.95	5.99	6.04	6.08	6.13	6.18	6.23
90	6.28	6.34	6.41	6.48	6.55	6.64	6.75	6.88	7.05	7.33
%	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
99	7.33	7.37	7.41	7.46	7.51	7.58	7.65	7.75	7.88	8.09

[1]D. J. Finney, *Probit Analysis*, (Cambridge: Cambridge University Press, 1971), p. 25. Reprinted by permission.

Table 2-5 Probit Correlations for a Variety of Exposures (The causative variable is representative of the magnitude of the exposure.)

Type of injury or damage	Causative variable	Probit parameters k_1	k_2
Fire[1]			
Burn deaths from flash fire	$t_e I_e^{4/3}/10^4$	−14.9	2.56
Burn deaths from pool burning	$t I^{4/3}/10^4$	−14.9	2.56
Explosion[1]			
Deaths from lung hemorrhage	p^o	−77.1	6.91
Eardrum ruptures	p^o	−15.6	1.93
Deaths from impact	J	−46.1	4.82
Injuries from impact	J	−39.1	4.45
Injuries from flying fragments	J	−27.1	4.26
Structural damage	p^o	−23.8	2.92
Glass breakage	p^o	−18.1	2.79
Toxic release[2]			
Ammonia deaths	$\Sigma C^{2.0} T$	−35.9	1.85
Carbon monoxide deaths	$\Sigma C^{1.0} T$	−37.98	3.7
Chlorine deaths	$\Sigma C^{2.0} T$	−8.29	0.92
Ethylene oxide deaths[3]	$\Sigma C^{1.0} T$	−6.19	1.0
Hydrogen chloride deaths	$\Sigma C^{1.0} T$	−16.85	2.0
Nitrogen dioxide deaths	$\Sigma C^{2.0} T$	−13.79	1.4
Phosgene deaths	$\Sigma C^{1.0} T$	−19.27	3.69
Propylene oxide deaths	$\Sigma C^{2.0} T$	−7.42	0.51
Sulfur dioxide deaths	$\Sigma C^{1.0} T$	−15.67	1.0
Toluene	$\Sigma C^{2.5} T$	−6.79	0.41

t_e = effective time duration (s)
I_e = effective radiation intensity (W/m^2)
t = time duration of pool burning (s)
I = radiation intensity from pool burning (W/m^2)
p^o = peak overpressure (N/m^2)
J = impulse (N s/m^2)
C = concentration (ppm)
T = time interval (min)

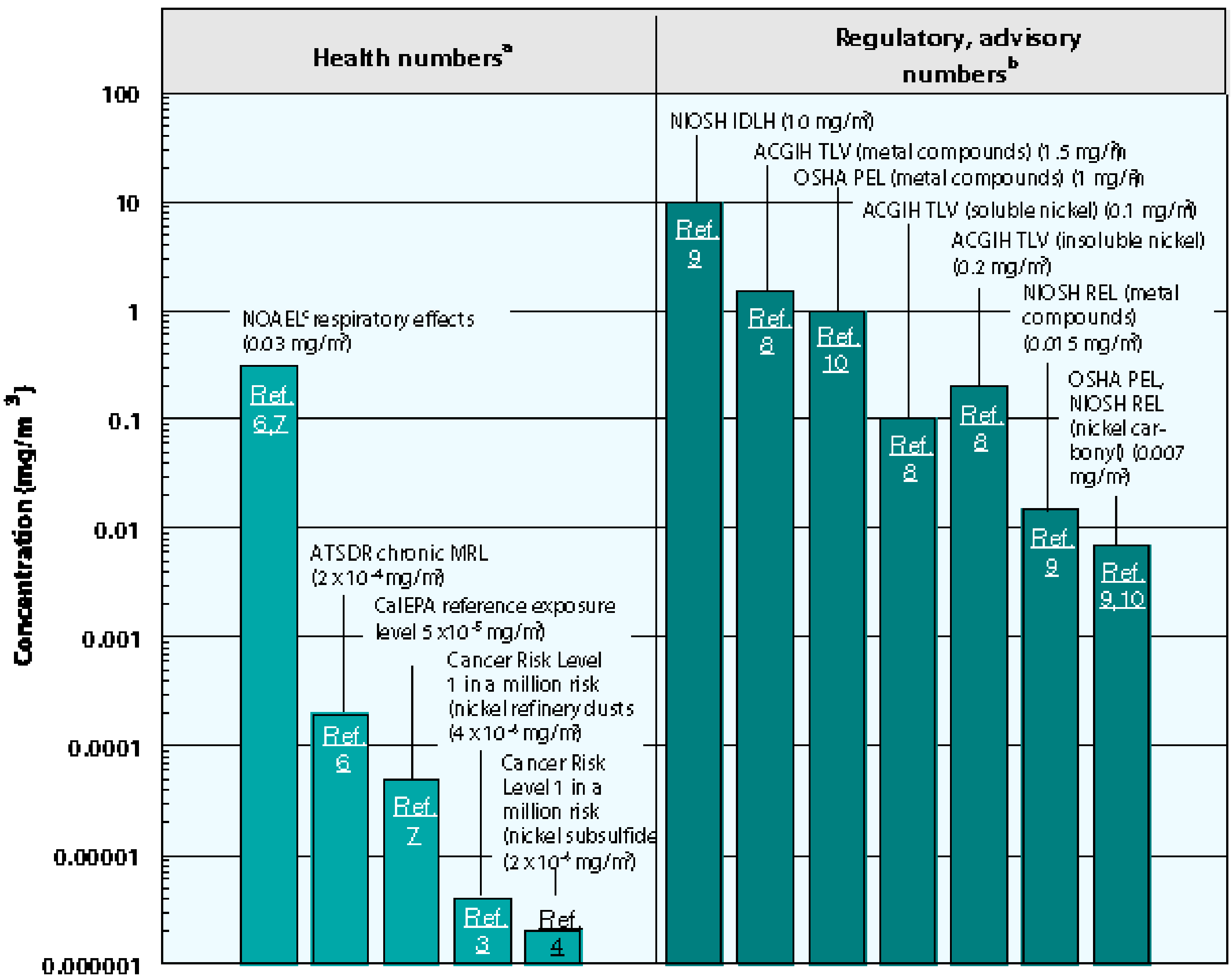
Toxic Gas Effect-1

- Toxic effect model
  - Assess the consequences to human health as a result of exposure to a known concentration of toxic gas for a known period of time
  - Toxicologic criteria and methods
    - Emergency Response Planning Guidelines for Air Contaminant (ERPGs) issued by AIHA (American Industrial Hygiene Association)

Toxic Gas Effect-2

- **Toxic effect model 2**
  - **Immediately Dangerous to Life or Health (IDLH) established by NIOSH(National Institute for Occupational Safety and Health)**
  - **Emergency Exposure Guidance Levels (EEGLS) and Short-term Public Emergency Guidance Levels (SPEGLs) issued by National Academy of Science**
  - **Threshold Limit Values (TLVs) established by ACGIH(American Conference of Governmental Industrial Hygienists)**
  - **Permissible Exposure Limit (PELs) promulgated by OSHA(Occupational Safety and Health Administration)**

Nickel



Health numbers[a]
Regulatory, advisory numbers[b]
Concentration (mg/m³)
100
10
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
NOAEL[c] respiratory effects (0.03 mg/m³)
Ref. 6,7
ATSDR chronic MRL (2 x 10⁻⁴ mg/m³)
Ref. 6
CalEPA reference exposure level 5 x 10⁻⁵ mg/m³
Ref. 7
Cancer Risk Level 1 in a million risk (nickel refinery dusts (4 x 10⁻⁶ mg/m³)
Ref. 3
Cancer Risk Level 1 in a million risk (nickel subsulfide (2 x 10⁻⁶ mg/m³)
Ref. 4
NIOSH IDLH (10 mg/m³)
Ref. 9
ACGIH TLV (metal compounds) (1.5 mg/m³)
Ref. 8
OSHA PEL (metal compounds) (1 mg/m³)
Ref. 10
ACGIH TLV (soluble nickel) (0.1 mg/m³)
Ref. 8
ACGIH TLV (insoluble nickel) (0.2 mg/m³)
Ref. 8
NIOSH REL (metal compounds) (0.015 mg/m³)
Ref. 9
OSHA PEL, NIOSH REL (nickel carbonyl) (0.007 mg/m³)
Ref. 9,10

Toxic Gas Effect-3

- ERPGs
  - Provide a consequence of exposure to a specific substance of maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hr without experiencing or developing
    - ERPG1
      - any symptoms other than mild transient adverse health effects or without perceiving a clearly defined objectionable odor
    - ERPG2
      - irreversible or other serious health effects or symptoms that could impair their abilities to take protective action
    - ERPG3
      - life-threatening health effects

TABLE 2.29. Emergency Response Planning Guidelines, ERPGs (AIHA, 1996). All values are in ppm unless otherwise noted. Values are updated regularly.

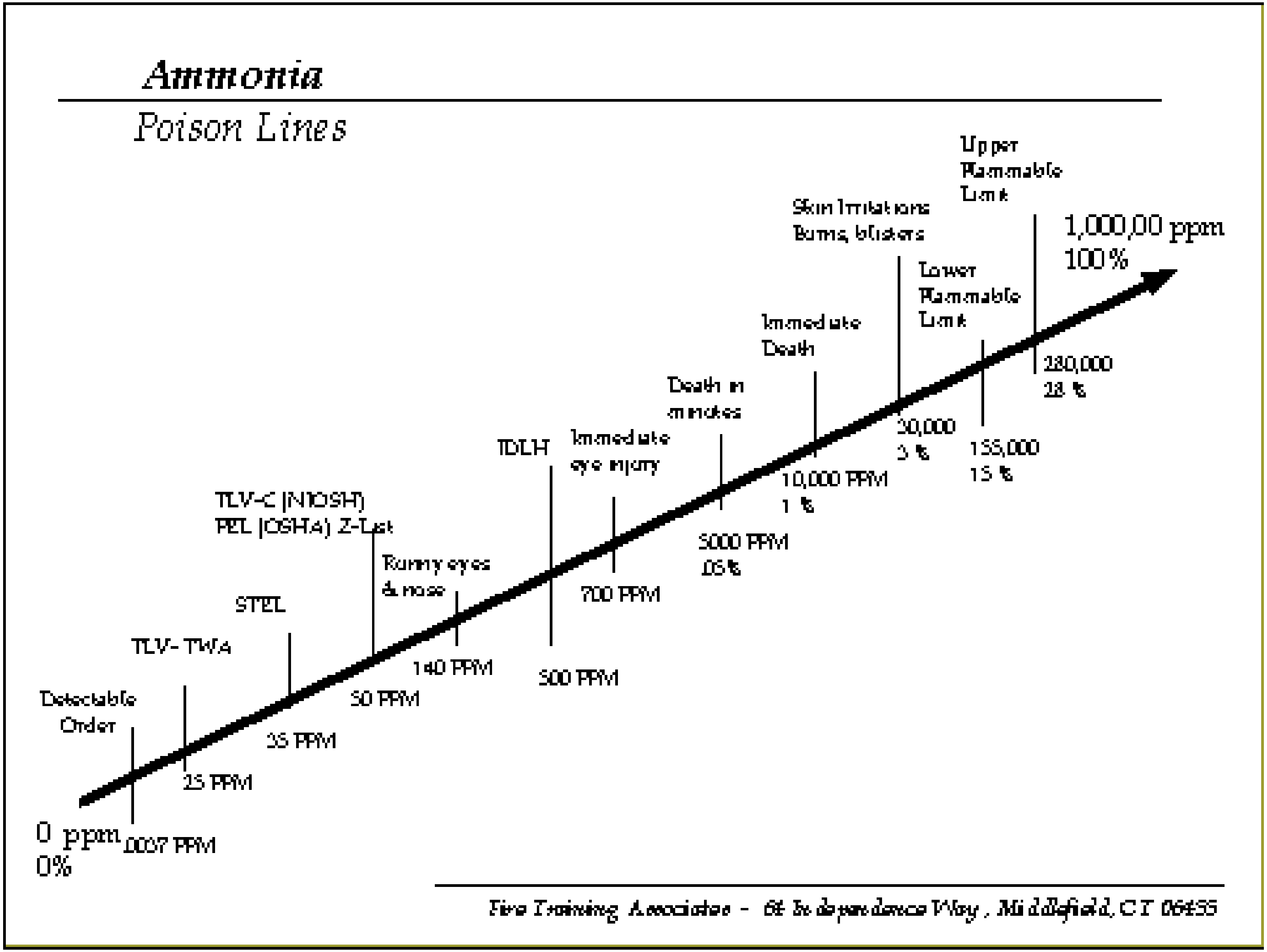
Chemical	ERPG-1	ERPG-2	ERPG-3
Acetaldehyde	10	200	1000
Acrolein	0.1	0.5	3
Acrylic Acid	2	50	750
Acrylonitrile	NA	35	75
Allyl Chloride	3	40	300
Ammonia	25	200	1000
Benzene	50	150	1000
Benzyl Chloride	1	10	25
Bromine	0.2	1	5
1,3-Butadiene	10	50	5000
n-Butyl Acrytate	0.05	25	250
n-Butyl Isocyanate	0.01	0.05	1
Carbon Disulfide	1	50	500
Carbon Tetrachloride	20	100	750
Chlorine	1	3	20
Chlorine Trifluouride	0.1	1	10
Chloroacetyl Chloride	0.1	1	10
Chloropicrin	NA	0.2	3
Chlorosulfonic Acid	2 mg/m^3	10 mg/m^3	30 mg/m^3
Chlorotrifluoroethylene	20	100	300
Crotonaldehyde	2	10	50
Diborane	NA	1	3
Diketene	1	5	50
Dimethylamine	1	100	500
Dimethylchlorosilane	0.8	5	25
Dimethyl Disulfide	0.01	50	250
Epichlorohydrin	2	20	100
Ethylene Oxide	NA	50	500
Formaldehyde	1	10	25
Hexachlorobutadiene	3	10	30
Hexafluoroacetone	NA	1	50
Hexafluoropropylene	10	50	500
Hydrogen Chloride	3	20	100
Hydrogen Cyanide	NA	10	25
Hydrogen Fluoride	54	20	50
Hydrogen Sulfide	0.1	30	100
Isobutyronitrile	10	50	200
2-Isocyanatoethyl Methacrylate	NA	0.1	1
Lithium Hydride	25 μgm/m^3	100 μgm/m^3	500 μgm/m^3
Methanol	200	1000	5000

(continued)

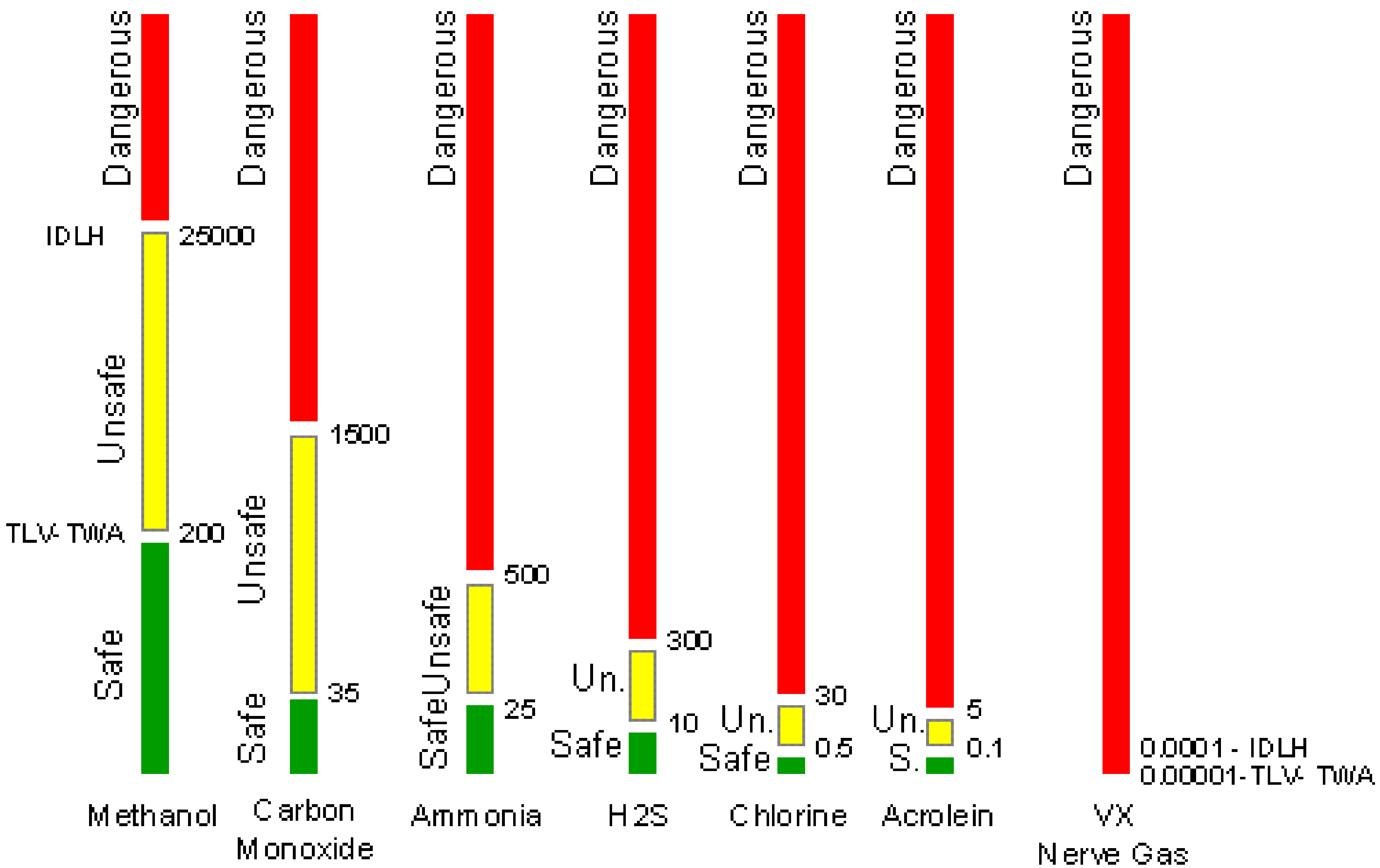
Toxic Gas Effect-4

- IDLHs
  - When exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment
  - Currently available for 380 materials

Contaminant	Concentration (ppm)		IDLH (ppm)
	Mean	Maximum	
Acrolein	1.9	98	5
Benzene	4.7 - 56	250	3,000
CO	246-1,450	27,000	1,500
HC1	0.8-13	280	100
HCN	0.14-5.0	75	50
NO_2	0.04-0.7	9.5	50
SO_2	2.3	42	100
Particulates*	232	15,000	n.a.


Ammonia
Poison Lines
Detectable Order
.0037 PPM
TLV- TWA
25 PPM
STEL
35 PPM
TLV-C (NIOSH)
PEL (OSHA) Z-List
50 PPM
Runny eyes & nose
140 PPM
IDLH
300 PPM
Immediate eye injury
700 PPM
Death in minutes
5000 PPM
.05%
Immediate Death
10,000 PPM
1 %
Skin Irritations
Burns, blisters
30,000
3 %
Lower Flammable Limit
155,000
15 %
Upper Flammable Limit
280,000
28 %
1,000,00 ppm
100 %
0 ppm
0%
Fire Training Associates - 64 Independence Way, Middlefield, CT 06455

Poison Line - Toxicity Relationships



Toxic Gas Effect-5

- EEGLs and SPEGLs
  - EEGL is define as a concentration of a gas, vapor or aerosol that is judged to be acceptable and that will allow healthy military personnel to perform specific tasks during emergency conditions lasting from 1 to 24 hr
  - SPEGLs defined as acceptable concentrations for exposures of members of the general public

Toxic Gas Effect-6

- **TLV-STEL**
  - **Maximum concentration to which workers can be exposed for a period of up to 15 minutes without suffering**
    - **Intolerable irritation**
    - **Chronic or irreversible tissue change**
    - **Narcosis of sufficient degree to increase accident proneness**

Toxic Gas Effect-7

- **PEL**
  - **Similar to the ACGIH criteria for TLV-TWAs since they are also based on 8-hr time-weighted average exposure**
- **Toxic endpoints**
  - **Used for air dispersion modeling of toxic gas released as part of the EPA Risk Management Plan(RMP)**
  - **Use ERPG2 or LOC(Level of Concern) by Emergency Planning and Community Right-to-Know Act**

TABLE 2.32. Probit Equation Constants for Lethal Toxicity

The probit equation is of the form

$$Y = a + b \ln(C^n t_e)$$

where

Y is the probit
a, b, n are constants
C is the concentration in ppm by volume
t_e is the exposure time in minutes

Substance	U.S. Coast Guard (1980)			World Bank (1988)		
	a	*b*	*n*	*a*	*b*	*n*
Acrolein	−9.931	2.049	1	−9.93	2.05	1.0
Acrylonitrile	−29.42	3.008	1.43			
Ammonia	−35.9	1.85	2	−9.82	0.71	2.00
Benzene	−109.78	5.3	2			
Bromine	−9.04	0.92	2			
Carbon Monoxide	−37.98	3.7	1			
Carbon Tetrachloride	−6.29	0.408	2.50	0.54	1.01	0.5
Chlorine	−8.29	0.92	2	−5.3	0.5	2.75
Formaldehyde	−12.24	1.3	2			
Hydrogen Chloride	−16.85	2.00	1.00	−21.76	2.65	1.00
Hydrogen Cyanide	−29.42	3.008	1.43			
Hydrogen Fluoride	−25.87	3.354	1.00	−26.4	3.35	1.0
Hydrogen Sulfide	−31.42	3.008	1.43			
Methyl Bromide	−56.81	5.27	1.00	−19.92	5.16	1.0
Methyl Isocyanate	−5.642	1.637	0.653			
Nitrogen Dioxide	−13.79	1.4	2			
Phosgene	−19.27	3.686	1	−19.27	3.69	1.0
Propylene Oxide	−7.415	0.509	2.00			
Sulfur Dioxide	−15.67	2.10	1.00			
Toluene	−6.794	0.408	2.50			

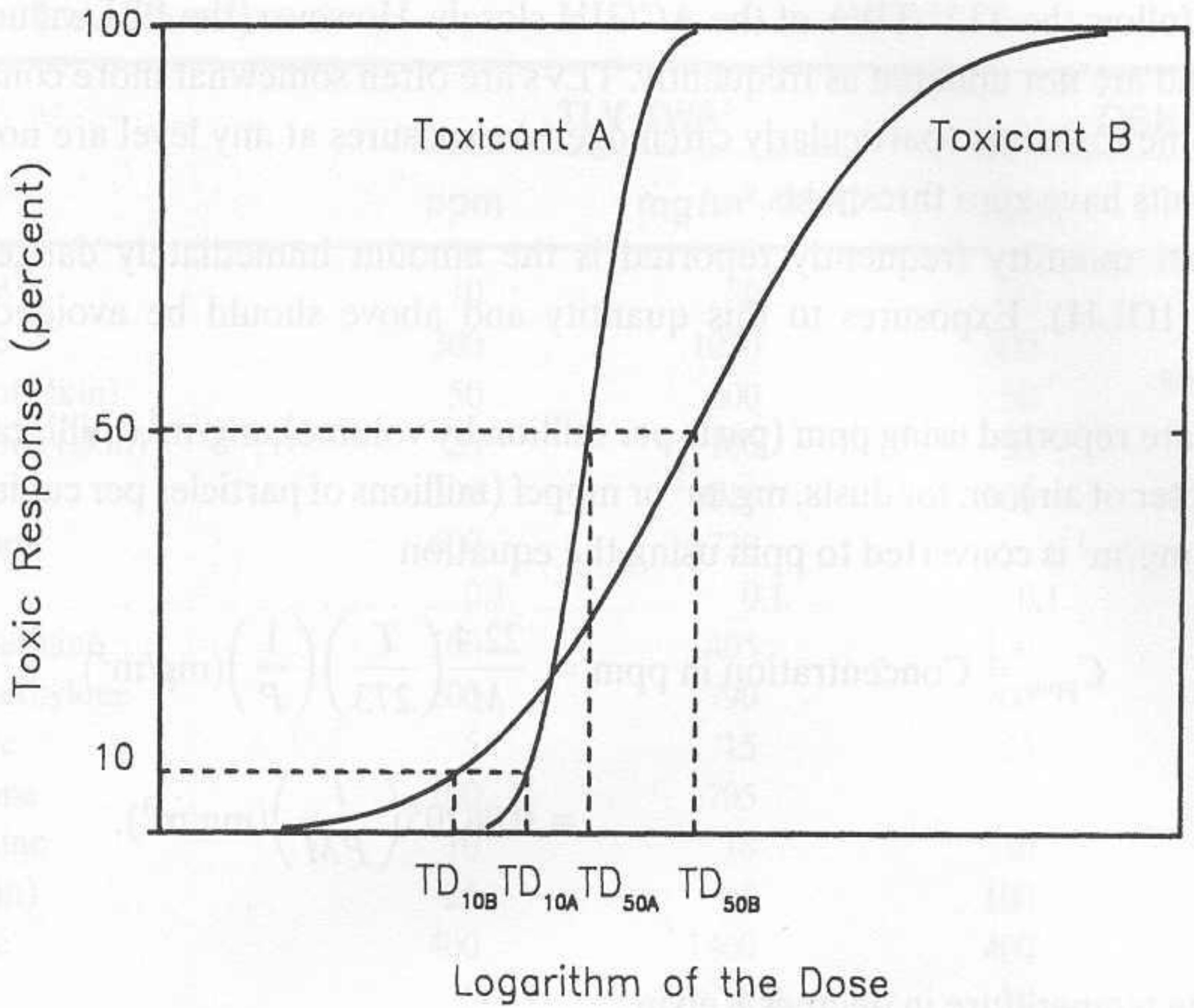


Figure 2-13 Two toxicants with differing relative toxicities at different doses. Toxicant A is more toxic at high doses, whereas toxicant B is more toxic at low doses.

Thermal Effects

- **Two approaches are used**
  - **Simple tabulations or charts based on experimental results**
  - **Theoretical models based on the physiology of skin burn response**
  - ***Probit* model (Eisenberg, 1975)**

$$Y = -14.9 + 2.56 \ln\left(\frac{tI^{4/3}}{10^4}\right)$$

    - **Y is the Probit**
    - **t is the duration of exposure(sec)**
    - **I is the thermal radiation intensity(W/m^2)**

TABLE 2.33. Exposure Time Necessary to Reach the Pain Threshold (API, 1966a)

Radiation intensity (Btu/hr/ft^2)	kW/m^2	Time to pain threshold (s)
500	1.74	60
740	2.33	40
920	2.90	30
1500	4.73	16
2200	6.94	9
3000	9.46	6
3700	11.67	4
6300	19.87	2

TABLE 2.34. Recommended Design Flare Radiation Levels Excluding Solar Radiation (API, 1996a)

Permissible design level (K)		
Btu/hr/ft^2	kW/m^2	Conditions[a]
5000	15.77	Heat intensity on structures and in areas where operators are not likely to be performing duties and where shelter from radiant heat is available, for example, behind equipment
3000	9.46	Value of K at design flare release at any location to which people have access, for example, at grade below the flare or on a service platform of a nearby tower. Exposure must be limited to a few seconds, sufficient for escape only
2000	6.31	Heat intensity in areas where emergency actions lasting up to 1 min may be required by personnel without shielding but with appropriate clothing
1500	4.73	Heat intensity in areas where emergency actions lasting several minutes may be required by personnel without shielding but with appropriate clothing
500	1.58	Value of K at design flare release at any location where personnel are continuously exposed

[a] On towers or other elevated structures where rapid escape is not possible, ladders must be provided on the side away from the flare, so the structure can provide some shielding when K is greater than 200 Btu/hr/ft^2 (6.31 kW/m^2).

TABLE 2.35. Effects of Thermal Radiation (World Bank, 1985)

Radiation intensity (kW/m^2)	Observed effect
37.5	Sufficient to cause damage to process equipment
25	Minimum energy required to ignite wood at indefinitely long exposures (nonpiloted)
12.5	Minimum energy required for piloted ignition of wood, melting of plastic tubing
9.5	Pain threshold reached after 8 sec; second degree burns after 20 sec
4	Sufficient to cause pain to personnel if unable to reach cover within 20 s. however blistering of the skin (second degree burns) is likely; 0% lethality
1.6	Will cause no discomfort for long exposure

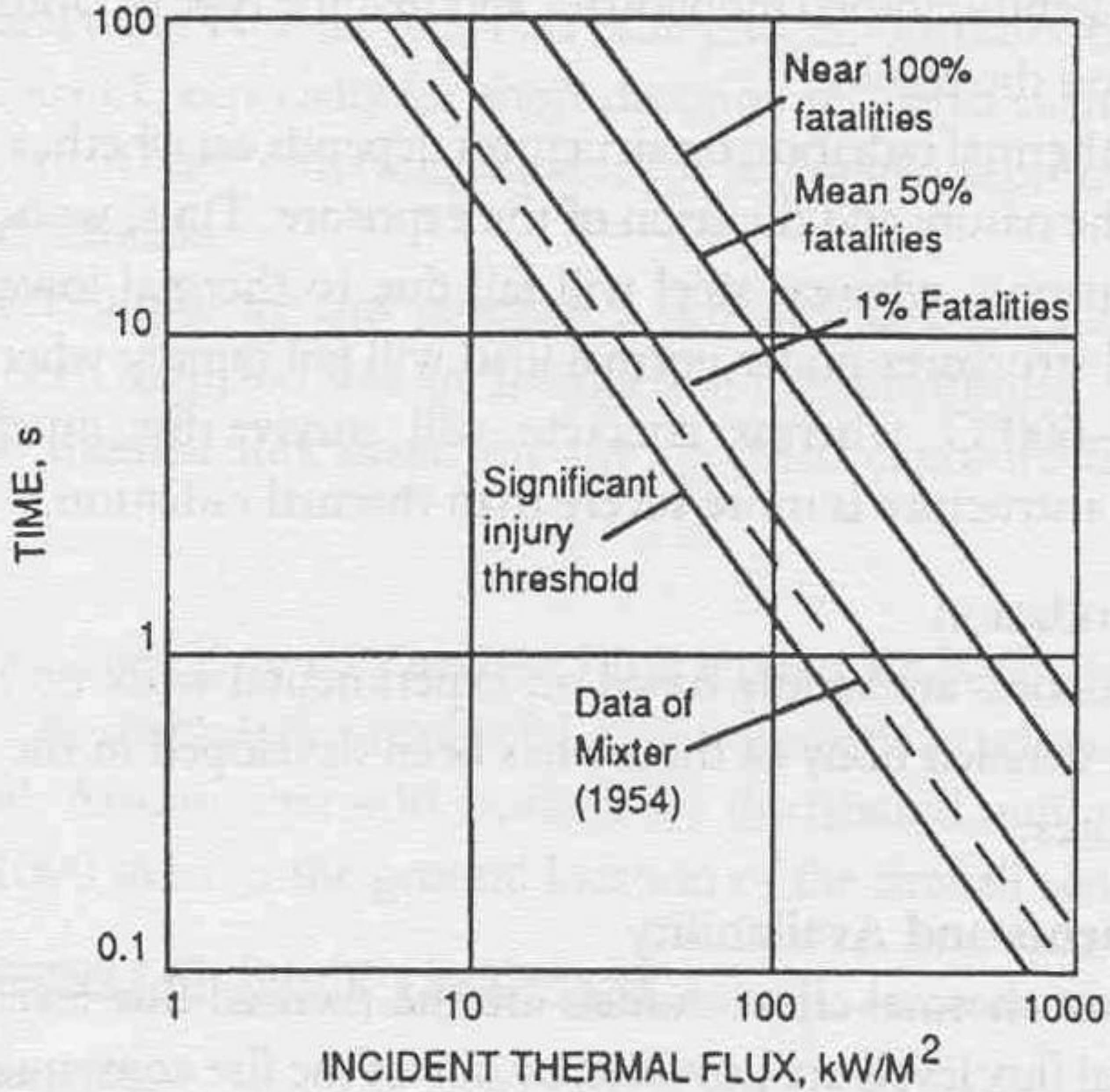


FIGURE 2.95. *Serious injury/fatality levels for thermal radiation (Mudan, 1984).*

Explosion Effects

- **Explosion effect**
  - **Based on either the blast overpressure alone, or a combination of blast over pressure, duration and/or specific impulse**
  - **Structure**

$$Y = -23.8 + 2.92\ln(P^0)$$

    - **Y is the *Probit***
    - **P^0 is the peak overpressure(Pa)**

  - **People**

$$Y = -77.1 + 6.91\ln(P^0)$$

Probit Equation; Example

Example

In a risk assessment study, one scenario involves a community of 1000 people being subjected to toxic chlorine vapors due to a truck accident. Given the data below, determine the potential deaths due to toxic exposure.

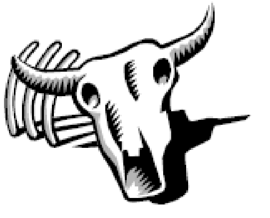
People Subjected	Exposure Time	Concentration
200	150	200
	50	100
	20	50

Solution:

$$P_r = -13.22 + (1.00)\ln\{\Sigma(C^{2.3}\Delta t)\}$$

$$P_r = 4.047$$

% = 17%, 34 people would die.



Relative Toxicity

- Toxicity degree varies widely with agent.
- Wide range of lethal doses from < 70 mg to > 1 kg for a 70 kg person in Tab 2-6, p. 54. (Dose/body weight)
- Effects of two toxins can be very different at low and high doses, Fig. 2-13, p. 55
- Response data are needed over wide ranges of doses to determine relative hazards of toxic agents.

Threshold Limit Values (TLV)

- TLV: threshold, adverse effect (ACGIH)
- Low doses < TLV < high doses
- body detoxifies adverse effects
- TLV-TWA: time weighted ave. 40 hr week during worker lifetime
- TLV-STEL: short term exposure limit < 15 min
- TLV-C: ceiling level must not be exceeded

TVL-TWA Model

$$TWA = \frac{1}{8}\int_{0}^{t_w} C(t)\,dt$$

where t_w is the worker shift in hours.
C(t) is the concentration of the toxin in air.

The integral is divided by 8 hours regardless of the time worked in the shift.

TLV-TWA Determination

- **TWA from intermittent measurements**

$$TWA = \frac{C_1T_1 + C_1T_2 + \cdots C_nT_n}{8\ hr}$$

- **where C_i is the concentration estimated to be the average concentration over the time interval T_i.**

Permissible Exposure Levels (PEL)

- **PEL by OSHA compared with TLV-TWA in Tab. 2-8, pp. 56-58.**
- **Where these threshold levels differ, use the lower levels**
- **Carcinogens: effects of levels unknown**
- **IDLH, immediately dangerous to life & health (NIOSH): max. permissible levels**