(asbestos)

(decision)

(tree)

Framework for Evaluating Asbestos Sites

USEPA/OSWER Asbestos Technical Review Workgroup

Arnold Den

United States Environmental Protection Agency

Region IX

San Francisco, CA

Special Thanks to:

- Jim Konz (HQ) and Mark Maddaloni (R2)
- Chuck Nace (R2)
- Brian Brass (ERT)
- Julie Wroble (R10)
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Overview

- Activity-Based Sampling
  - What is it?
  - Why do it?
- Asbestos definitions
- Asbestos environmental sampling and analysis
- Asbestos Site Assessment Framework
- Asbestos Risk Assessment

Asbestos Exposure Assessment

- Measurements made directly from the breathing zone are most appropriate for incidental soil exposures
- Measurements from stationary monitors may not provide reliable estimates of human inhalation exposure
- Solid media (e.g., soil or dust) measurements cannot be reliably converted to derive airborne exposure concentrations

Why Activity-Based Sampling?

- OSWER Directive 9345.4 (Cook memo)
- Soil concentrations <1% demonstrated to represent significant risk
- Correlation between potential release of asbestos from soil and inhalable fibers not well defined & methods not standardized
- Resuspension of PM from human activity produces a measurable personal cloud
  - (Lynn Hildemann, Stanford University March 2005)
- Empirical results indicate ABS is the appropriate methodology

Activity-Based Sampling (ABS)

Generic & Site-specific ABS

- **Generic Outdoor ABS** utilizes a rake to disturb the soil over a known area in conjunction with the collection of air samples.
  - Evaluate the potential for fiber release from soil over a large area.
- **Generic Indoor ABS** utilizes fans to disturb settled dust in conjunction with the collection of air samples
  - Evaluate the potential for fiber release from dust
- **Site-Specific Outdoor or Indoor ABS** utilizes simulated activities to disturb source
  - Based likely site activities to evaluate exposure

Activity-Based Outdoor Sampling

- Uses an activity that provides a high-end soil disturbance
- Currently recommend a “raking scenario”
- Rake for specified time over a template area
- Collect personal air samples (breathing zone) and perimeter air samples
- Provides a measure of fiber release from soil

Hiking

ATV Riding

Bicycling

Soccer

Walking with Stroller

Motorcycling on Unpaved Road/Trail

Driving on Unpaved Road/Trail

Rototilling

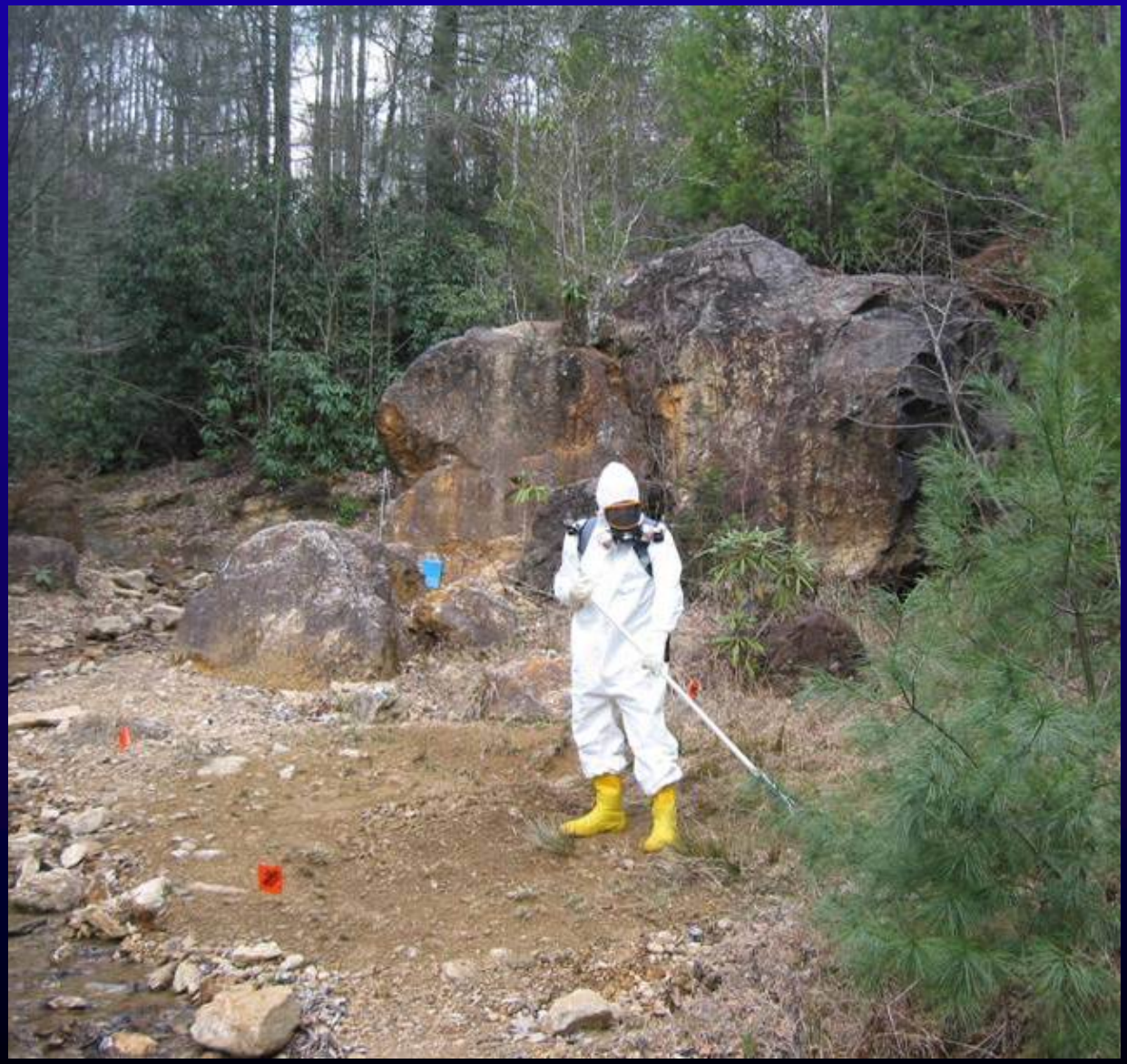
Gardening

Child in Dirt with Bucket

Mowing

Digging

Raking



Weed whacking

Activity-Based Indoor Sampling

- Activity-based sampling, if possible
- Generic use of fans/leaf blower may be used
- Collect air samples (breathing zone) and perimeter air samples
- Provides quantitative concentration of fibers in air resulting from dust disturbance

Alternative Indoor Sampling:
Microvacuum

- ASTM 5755 method
- Low-suction vacuum
- Captures dust and fibers on filter cassette
- Preserves dust matrix
- Provides a **qualitative** measure of fibers in settled dust

Asbestos

Definitions
Types
Shapes
Examples

Asbestos: What is It ?

Asbestos may be defined

- Commercially
  - Materials used for industrial activities
- Regulatory
  - Materials regulated by agencies and organizations
- Geologically
  - Mineralogically – mineral type
  - Morphologically – size, habit
- Analytically
  - What is seen under microscope

Asbestos: Commercial Definition

- Naturally occurring mineral fibers
- Selected for useful properties
  - Long flexible mineral fibers
  - High tensile strength
  - Durability
  - Heat resistance
  - Acid/alkaline resistance (amphiboles)
- The general term asbestos was applied to mineral fibers selected for these uses

Asbestos: Regulatory Definition

- Occupational Safety and Health Administration (29 CFR 1910.1001)
  - Chrysotile
  - Amosite
  - Crocidolite
  - Anthophyllite
  - Actinolite
  - Tremolite
- U.S. Environmental Protection Agency
  - CERCLA/RCRA
  - Toxic Substances Control Act
  - Clean Air Act
  - NESHAPs
  - AHERA

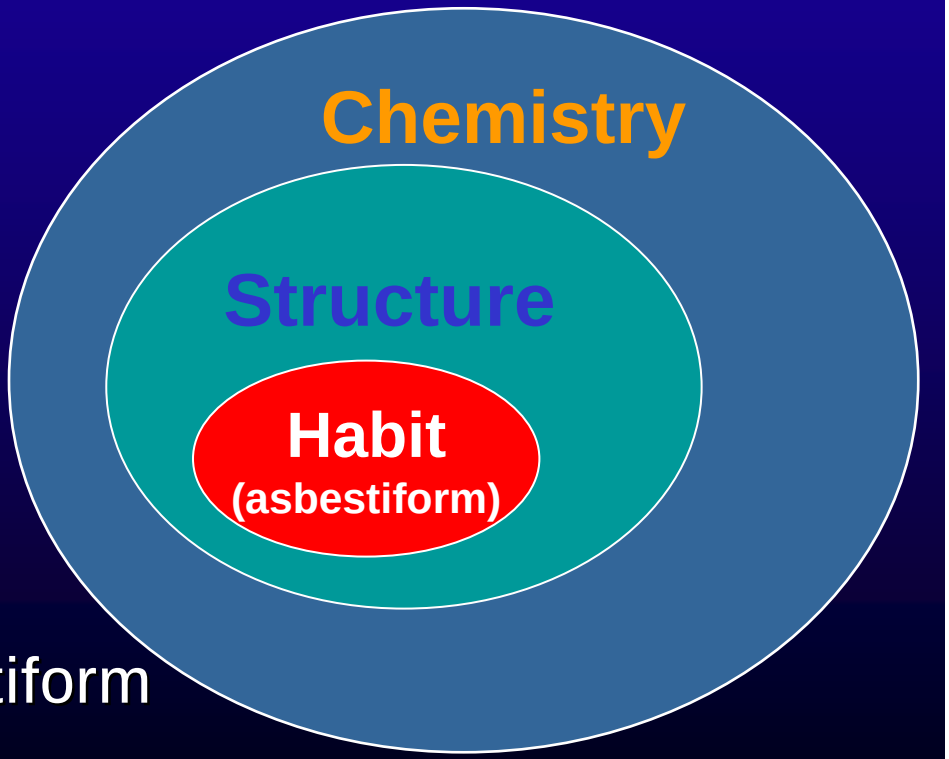
Asbestos: Mineralogical Definition

American Chemical Society

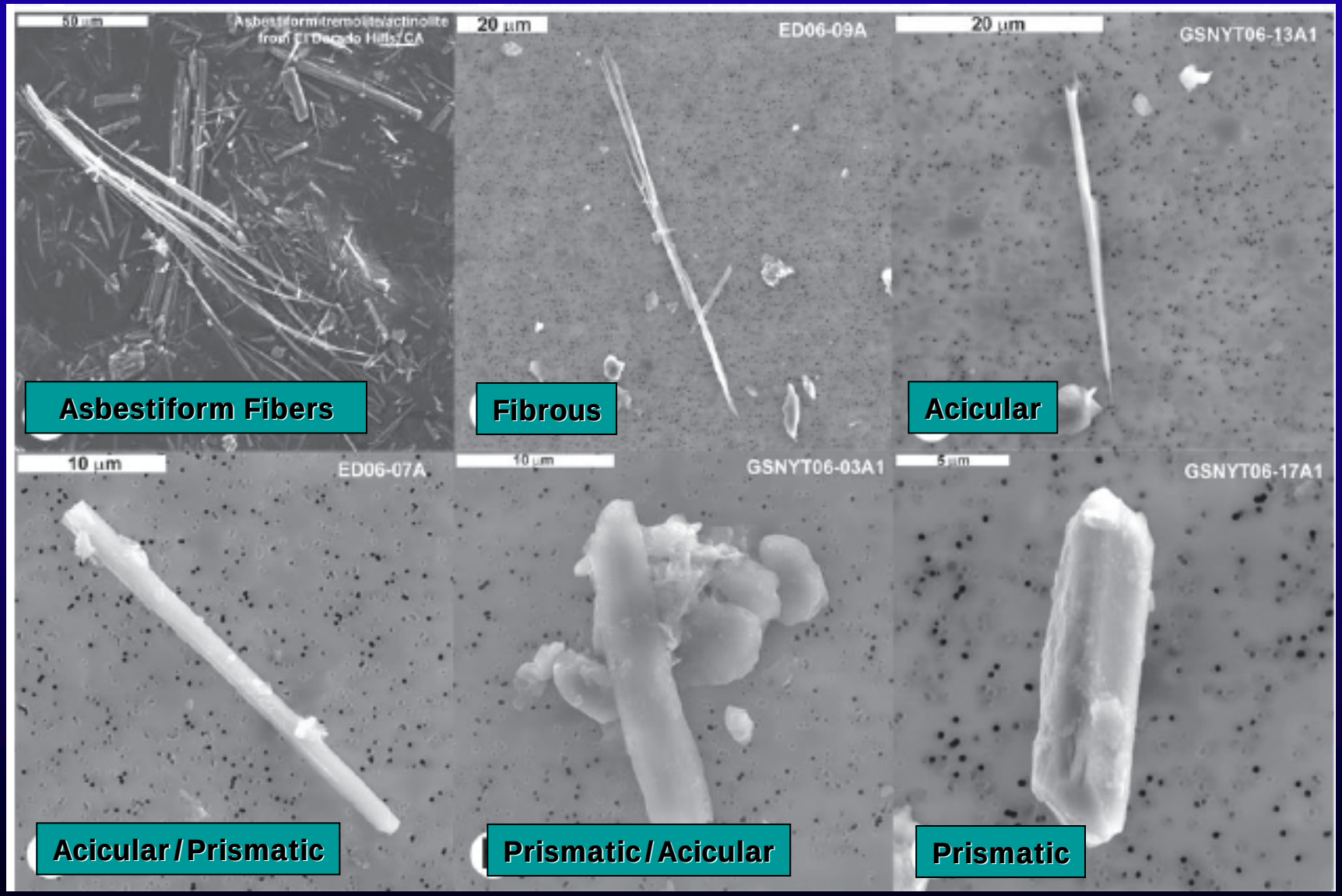
- CAS No. 1332-21-4
- “A grayish, noncombustible fibrous material. It consists primarily of impure magnesium silicate minerals.”

Asbestos: Geological Definition

- Silicate Minerals – basic chemistry
  - Silicon and oxygen
  - Tetrahedron shaped ionic group
    - (SiO_4)
- Further classification
  - Structure
  - Cations present
    - (Ca, Fe^{+2}, Al, Mg, etc.)
  - Habit of formation
    - Asbestiform/non-asbestiform
    - Massive

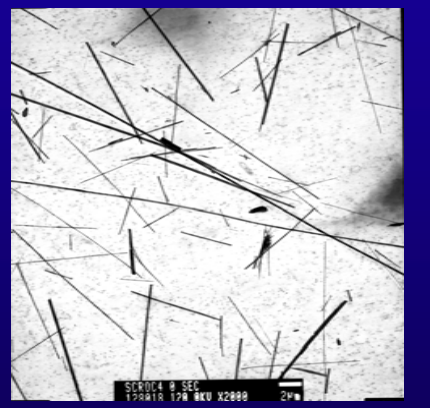


Morphology - Structures



Asbestos: Analytical Definition

- Historical exposure measurements
  - Total mineral dust (mg/m^3)
  - Early filter collection - membrane filter (f/m^3)
- "Fiber" metric used to establish the EPA IRIS Inhalation Unit Risk
  - Phased contrast microscopy (PCM)
  - Surrogate measure of material present
- "Fiber" defined by resolution instrument and counting rules applied
  - e.g., Transmission electron microscope (TEM)
- Different agencies and organizations have different counting rules



What is the appropriate definition for risk assessment?

- Which materials are toxic?
  - All fibrous silicates?
  - Only fibers with a certain crystal form? (Inosilicates?)
  - Cleavage fragments versus asbestiform versus non-asbestiform
- What attributes of the materials are critical to its toxicity?
  - Dimensional characteristics
    - Length, width, aspect ratio
  - Chemistry – surface activity
  - Structure and habit of formation
- What metric should be used?
  - Fiber count
  - Surface area
  - Mass

Asbestos: Framework Definition

- Asbestos: The generic name used for a group of naturally occurring mineral silicate fibers of the serpentine and amphibole series, displaying similar physical characteristics although differing in composition.

Sampling Recommendations

Solid Media (soil/dust)

Air

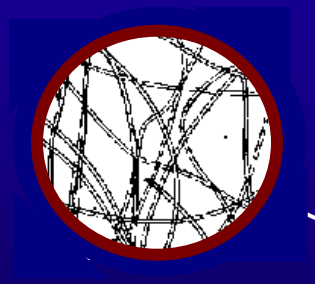
Solid Media Sampling

- Polarized light microscopy (PLM), an optical form, is a useful screening tool if large quantities of asbestos are present
- Non-detects with PLM do NOT mean there is no asbestos present – levels may be too low to been seen by PLM
- PLM not useful for soils below 0.2 to 0.25%

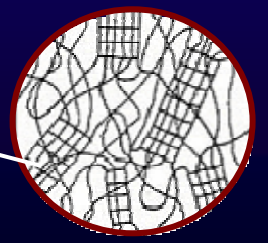
Air Sampling

- Is needed for meaningful human exposure assessment
- Should be done in the breathing zone if it's to be used for risk evaluation
- ABS – Activity- based sampling should be done while performing an activity typical for the site (e.g., raking, jogging, gardening)
  - [RME principle → take air samples during dust-generating activities (passive air samples may not reflect potential exposure)]
- Measure and characterize all fiber sizes (dimension) and fiber types (mineralogy)

Fibers in Breathing Zone



Fibers on Desk



Fibers Entrained in Carpet


Fibers in Breathing Zone
Fibers on Desk
Fibers Entrained in Carpet

Exposure Assessment Summary

- Measurements **made directly from the breathing zone** are most valuable
- Measurements from stationary monitors **do not** provide reliable estimates of human inhalation exposure
- **Dust** measurements and/or **solid media** (soil, ore, etc.) measurements are extremely difficult to convert to estimation of risk

Exposure Assessment Summary

Key points:

1.) Measurements from stationary air monitors may not provide reliable estimates of human inhalation exposure

Challenge: To efficiently obtain snapshot sample to predict long-term exposure

2.) Difficulty in converting **dust** measurements and/or **solid media** (soil, ore, ACM, etc.) data to estimation of risk

Challenge: To understand the factors that influence re-entrainment of fibers from solid matrices

Analytical Recommendations

- Sample analysis issues
- Analysis of air samples
- Analysis of dust samples
- Definition of PCMe fiber

Sample Analysis Issues

- Air analysis (stationary)
  - 2 alternatives
    - Phased Contrast Microscopy (PCM)
    - Transmission Electron Microscopy (TEM)
  - Expressed as fibers per volume of air (f/cc)
- Settled dust analysis
  - Transmission Electron Microscopy (TEM)
  - Expressed as fibers per unit area (f/cm^2)
- Bulk material analysis (soil etc.)
  - More complicated
  - Percent weight
    - Visual area estimates; point counting; gravimetric surrogate (Polarized Light Microscopy PLM)
    - Analytical sensitivity for asbestos in soil

How do these relate to exposure to air in breathing zone?

Analysis of Air Samples

- Instrumentation
  - Conventionally by PCM (400 x)
  - TEM (up to 40,000 x)
- Counting Rules
  - AHERA, ISO, & Superfund have different counting rules
    - Depending on the purpose, you may count more or fewer fibers
      - Risk assessment (PCME)
      - Cleaning efficiency (AHERA)

Analysis of Dust Samples

- TEM – PCMe analysis (asbestos fibers >5 µm)
- TEM – AHERA analysis (asbestos fibers >0.5 µm)
  - No regulatory standards for interpreting results
- No standards for interpreting results from settled dust (mass percent or fiber load) from vacuum or wipe
- Indirect prep may alter fiber number/dimension
- Minimum sensitivity ~250 f/cm^2 (wipe and microvacuum methods)
- Matrix interference → higher detection limits

Definition of PCMe Fiber

- EPA recommends modification of the [ISO Method] aspect ratio to 3:1 for this counting scheme.
- The other counting scheme allows for the counting of PCM equivalent fibers, or PCMe.
  - fibers that are longer than 5 µm in length
  - aspect ratios of 3:1 or greater.
  - PCMe fibers and structures under the ISO method also have a defined width range of between 0.2 µm and 3.0 µm. Note that EPA recommends a width range between 0.25 µm and 3.00 µm, as recommended by World Health Organization [WHO, 1986].)
- The purpose of counting fibers as PCMe fibers is that the method is attempting to mimic the size fraction of fibers that would be detected if the sample were being run under PCM. EPA's IRIS toxicity values for asbestos were historically generated from data based on PCM analyses.

TRW Asbestos Committee

- Develops new guidance for site assessment at hazardous waste sites contaminated by asbestos
- Provides site consultation in support of Regional requests for technical assistance
  - The committee is available to provide site-specific support to application of the framework
- Identifies research needs–data gaps in asbestos site assessment and risk assessment

Background
– Cleanup versus Risk-based –

- 1% in soil historically used as clean-up level – NOT risk-based
- August 2004 Cook memo rescinded 1%
  - Regions should develop risk-based, site-specific action levels based on air concentrations
  - “an accurate exposure value could only be determined through site sampling techniques that generate [airborne] fibers from soil”

Why Doesn't 1% Work?

- Asbestos NOT uniformly distributed in soil
  - 2 aliquots of same soil sample can yield vastly different asbestos concentrations (ND to > 1%)
- Risk assessment CANNOT predict inhalation exposure & risk from soil concentration using 1% because
  - soils w/ asbestos levels below 1% can create high risk inhalation exposures when disturbed
  - "1 percent threshold for asbestos in soil/debris . . . may not be protective of human health in all instances"

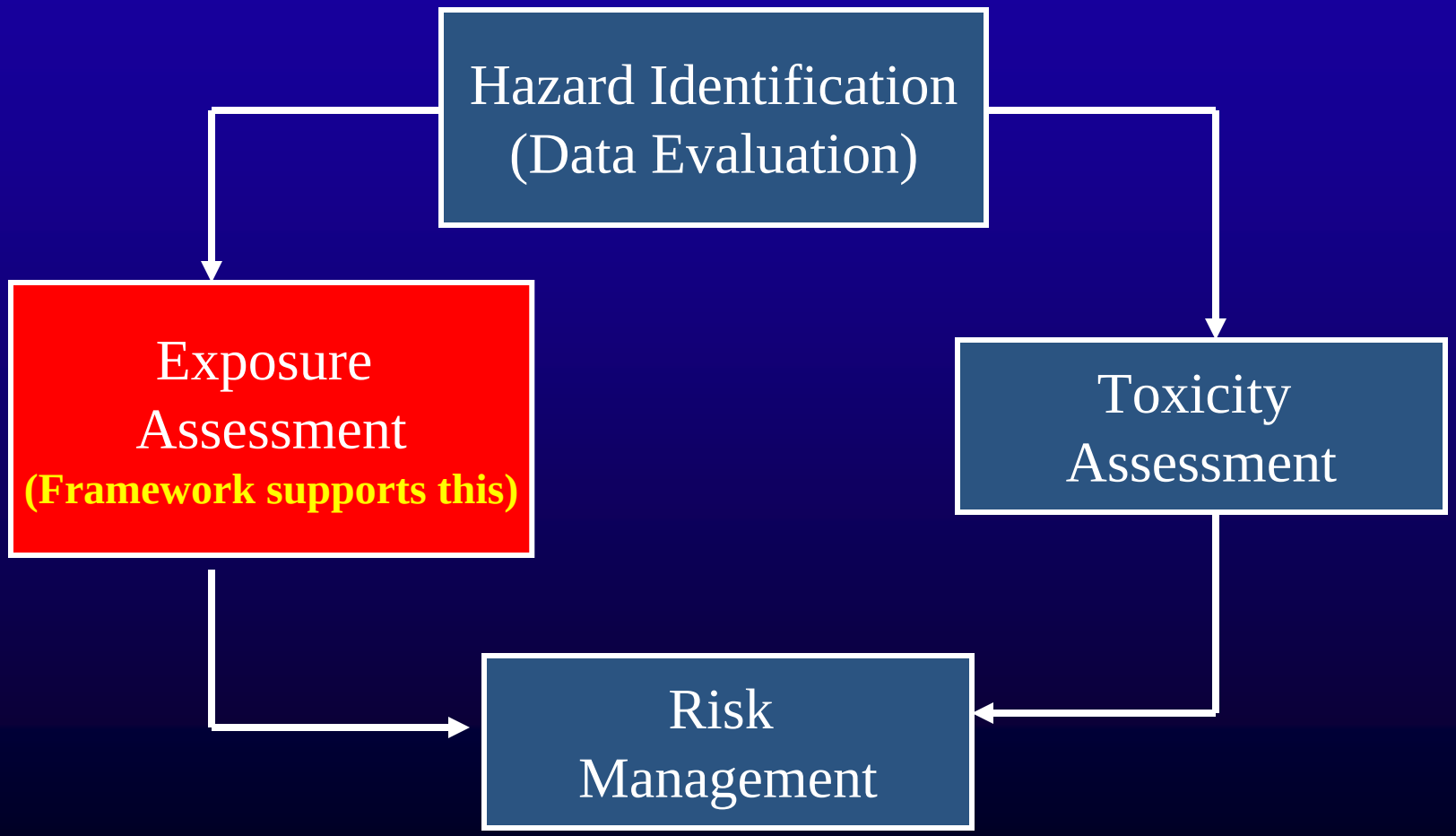
Key Recommendations:
The Framework

- Is risk-based investigation of exposure
- Is applicable to removal and remedial sites
- Addresses outdoor and indoor exposures
- Uses the latest sampling analytical methodologies
- Allows users to take response action at any point in the process

Asbestos Risk – More Information

- Risk assessment process
- Hazard ID
- Toxicity assessment
- Lifetime risk estimates
- Unit risks
- Agency activities

Risk Assessment Process



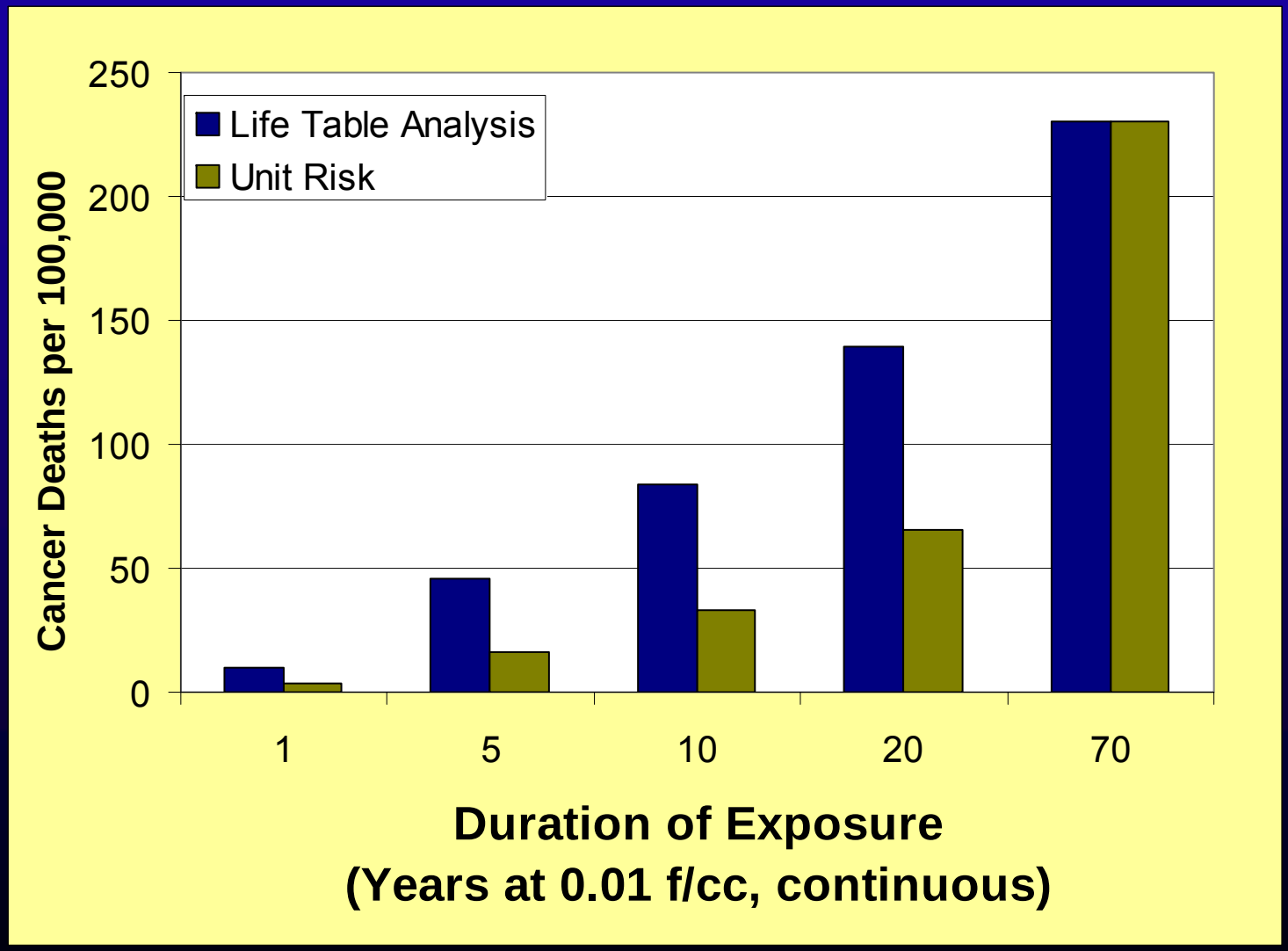
Hazard Identification

- Which materials are toxic?
  - All fibrous silicates?
  - Only fibers with a certain crystal form? (Inosilicates?)
  - Cleavage fragments versus asbestiform
- What attributes of the materials are critical to its toxicity?
  - Dimensional characteristics
    - Length, width, aspect ratio
  - Chemistry – surface activity
  - Structure and habit of formation
- What metric should be used?
  - Fiber count
  - Surface area
  - Mass

Toxicity Assessment

- No Reference Concentration to address non-cancer health effects
- IRIS Inhalation Unit Risk
  - Addresses lung cancer and mesothelioma
  - PCM fiber as surrogate for exposure
  - Based on commercial grade asbestos
    - Chrysotile (6), Amosite (1) Mixed (4)
- Less-than-lifetime exposures
  - Early-life exposures
  - Lifetime risk of cancer may be underestimated by unit risk

Lifetime risk estimates from less-than-lifetime exposures



Risk Assessment Calculations

- USEPA Risk Assessment Guidance for Superfund
  - Primary guidance for evaluating exposure to hazardous substances, including asbestos
  - Use default parameters, or site-specific parameters when available, for receptor populations
  - Parameters include exposure frequency and exposure duration
  - Combined with inhalation reference value to determine potential risk
  - Rearrange formula to derive cleanup goals

Developing Risk-based Criteria

- Screening values, risk estimates, and preliminary remediation goals developed from the inhalation unit risk (IRIS)
- Uncertainty analysis can be used to provide bounding estimates in certain situations:
  - Less than lifetime exposures
  - Exposure to predominately amphibole fibers

Risk Assessment Formulas

Estimating Asbestos Risk

Risk = (Ca x ET x ED x EF x IUR)/(AT)

Activity	Risk	Ca	ET	EF	ED	IUR	AT
Lifetime	1E -04	**0.00043**	1	365	70	0.23	25550
Residential Indoor	1E -04	**0.001**	1	365	30	0.23	25550
Gardening	1E -04	**0.018**	0.417	50	30	0.23	25550
Jogging	1E -04	**0.053**	0.083	250	10	0.23	25550

- Ca = Concentration in air (f/cc)
- ET = Exposure time (hours/day); 12 hours/day = 0.5
- EF = Exposure frequency (days)
- ED = Exposure duration (years)
- IUR = Inhalation Unit Risk – 0.23 f/cc from IRIS
- AT = Average time (days); 365 of days/year x lifetime (70 years) = 25550 days

Risk Assessment Formulas

Calculating Preliminary Remediation Goal

$$CA = (Risk \times AT)/(ET \times ED \times EF \times IUR)$$

Activity	ET (hours/day)	EF (days)	ED (years)	AT (days)	IUR (f/cc)	Risk	**Remediation Goal (f/cc)**
Lifetime	1	365	70	25550	0.23	1E -04	**0.00043**
Residential Indoors	1	365	30	25550	0.23	1E-04	**0.00101**
Gardening	0.417	50	30	25550	0.23	1E -04	**0.018**
Jogging	0.083	250	10	25550	0.23	1E-04	**0.053**

Unit Risk Factors (Life Table)

Based on Table 6-3 from USEPA 1986

Age at Onset (years)	Duration of Exposure (years)				
	1	5	10	20	LT
0	0.010	0.046	0.084	0.140	0.23
10	0.007	0.031	0.058	0.094	0.148
20	0.005	0.021	0.038	0.063	0.093
30	0.003	0.014	0.025	0.042	0.056
50	0.001	0.006	0.010	0.014	0.015

Less than Lifetime Exposures

$$CA = (Risk \times AT)/(ET \times ED \times EF \times IUR)$$

Activity	ET (hours/ day)	EF (days)	ED (years)	AT (days)	IUR (f/cc)	Risk	**Remediation Goal (f/cc)**
Jogging Lifetime	0.083	250	10	25550	0.23	1E -04	**0.053**
Jogging Begin at 20	0.083	250	10	25550	0.038	1E-04	**0.32**
Jogging Begin at 30	0.083	250	10	25550	0.025	1E -04	**0.49**
Jogging Begin at 50	0.083	250	10	25550	0.010	1E-04	**1.23**

TABLE E-4

Extrapolated Unit Risk Values for Continuous and Less-Than-Lifetime Exposures (PCM f/cc)[3]

Age at Onset	Exposure Duration (years)																		
	1	2	3	4	5	6	8	10	12	14	16	20	24	25	30	40	50	60	LT
0	1.0E-02	2.0E-02	3.0E-02	3.9E-02	4.7E-02	5.5E-02	7.1E-02	8.5E-02	9.8E-02	1.1E-01	1.2E-01	1.4E-01	1.5E-01	1.6E-01	1.7E-01	1.9E-01	2.1E-01	2.2E-01	2.3E-01
1	9.9E-03	1.9E-02	2.8E-02	3.7E-02	4.5E-02	5.3E-02	6.8E-02	8.1E-02	9.4E-02	1.0E-01	1.2E-01	1.3E-01	1.5E-01	1.5E-01	1.7E-01	1.9E-01	2.0E-01	2.1E-01	2.2E-01
2	9.6E-03	1.9E-02	2.7E-02	3.6E-02	4.4E-02	5.1E-02	6.5E-02	7.8E-02	9.0E-02	1.0E-01	1.1E-01	1.3E-01	1.4E-01	1.5E-01	1.6E-01	1.8E-01	1.9E-01	2.0E-01	2.1E-01
3	9.2E-03	1.8E-02	2.6E-02	3.4E-02	4.2E-02	4.9E-02	6.3E-02	7.5E-02	8.7E-02	9.7E-02	1.1E-01	1.2E-01	1.4E-01	1.4E-01	1.5E-01	1.7E-01	1.8E-01	1.9E-01	2.0E-01
4	8.8E-03	1.7E-02	2.5E-02	3.3E-02	4.0E-02	4.7E-02	6.0E-02	7.2E-02	8.3E-02	9.3E-02	1.0E-01	1.2E-01	1.3E-01	1.3E-01	1.5E-01	1.6E-01	1.8E-01	1.8E-01	1.9E-01
5	8.5E-03	1.7E-02	2.4E-02	3.2E-02	3.9E-02	4.6E-02	5.8E-02	7.0E-02	8.0E-02	8.9E-02	9.8E-02	1.1E-01	1.3E-01	1.3E-01	1.4E-01	1.6E-01	1.7E-01	1.7E-01	1.9E-01
6	8.2E-03	1.6E-02	2.3E-02	3.1E-02	3.7E-02	4.4E-02	5.6E-02	6.7E-02	7.7E-02	8.6E-02	9.4E-02	1.1E-01	1.2E-01	1.2E-01	1.3E-01	1.5E-01	1.6E-01	1.7E-01	1.8E-01
7	7.9E-03	1.5E-02	2.3E-02	2.9E-02	3.6E-02	4.2E-02	5.4E-02	6.4E-02	7.4E-02	8.3E-02	9.1E-02	1.0E-01	1.2E-01	1.2E-01	1.3E-01	1.4E-01	1.5E-01	1.6E-01	1.7E-01
8	7.6E-03	1.5E-02	2.2E-02	2.8E-02	3.5E-02	4.1E-02	5.2E-02	6.2E-02	7.1E-02	7.9E-02	8.7E-02	1.0E-01	1.1E-01	1.1E-01	1.2E-01	1.4E-01	1.5E-01	1.5E-01	1.6E-01
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10	7.0E-03	1.4E-02	2.0E-02	2.6E-02	3.2E-02	3.8E-02	4.8E-02	5.7E-02	6.6E-02	7.3E-02	8.0E-02	9.2E-02	1.0E-01	1.0E-01	1.1E-01	1.3E-01	1.4E-01	1.4E-01	1.5E-01
11	6.8E-03	1.3E-02	1.9E-02	2.5E-02	3.1E-02	3.6E-02	4.6E-02	5.5E-02	6.3E-02	7.1E-02	7.7E-02	8.9E-02	9.8E-02	1.0E-01	1.1E-01	1.2E-01	1.3E-01	1.3E-01	1.4E-01
12	6.5E-03	1.3E-02	1.9E-02	2.4E-02	3.0E-02	3.5E-02	4.4E-02	5.3E-02	6.1E-02	6.8E-02	7.4E-02	8.5E-02	9.4E-02	9.6E-02	1.0E-01	1.2E-01	1.2E-01	1.3E-01	1.4E-01
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16	5.6E-03	1.1E-02	1.6E-02	2.1E-02	2.6E-02	3.0E-02	3.8E-02	4.5E-02	5.2E-02	5.8E-02	6.3E-02	7.2E-02	8.0E-02	8.2E-02	8.9E-02	9.8E-02	1.0E-01	1.1E-01	1.1E-01
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18	5.2E-03	1.0E-02	1.5E-02	1.9E-02	2.4E-02	2.8E-02	3.5E-02	4.2E-02	4.8E-02	5.3E-02	5.8E-02	6.7E-02	7.4E-02	7.5E-02	8.1E-02	9.0E-02	9.5E-02	9.8E-02	1.0E-01
19	5.1E-03	9.9E-03	1.4E-02	1.9E-02	2.3E-02	2.7E-02	3.4E-02	4.0E-02	4.6E-02	5.1E-02	5.6E-02	6.4E-02	7.1E-02	7.2E-02	7.8E-02	8.6E-02	9.1E-02	9.4E-02	9.8E-02
20	4.9E-03	9.5E-03	1.4E-02	1.8E-02	2.2E-02	2.6E-02	3.3E-02	3.9E-02	4.4E-02	4.9E-02	5.4E-02	6.2E-02	6.8E-02	6.9E-02	7.5E-02	8.3E-02	8.7E-02	9.0E-02	9.3E-02
21	4.7E-03	9.2E-03	1.3E-02	1.7E-02	2.1E-02	2.5E-02	3.1E-02	3.7E-02	4.3E-02	4.7E-02	5.2E-02	5.9E-02	6.5E-02	6.6E-02	7.2E-02	7.9E-02	8.3E-02	8.6E-02	8.9E-02
22	4.5E-03	8.8E-03	1.3E-02	1.7E-02	2.0E-02	2.4E-02	3.0E-02	3.6E-02	4.1E-02	4.6E-02	5.0E-02	5.7E-02	6.2E-02	6.3E-02	6.9E-02	7.6E-02	8.0E-02	8.2E-02	8.5E-02
23	4.4E-03	8.5E-03	1.2E-02	1.6E-02	2.0E-02	2.3E-02	2.9E-02	3.5E-02	3.9E-02	4.4E-02	4.8E-02	5.4E-02	6.0E-02	6.1E-02	6.6E-02	7.2E-02	7.6E-02	7.8E-02	8.1E-02
24	4.2E-03	8.2E-03	1.2E-02	1.6E-02	1.9E-02	2.2E-02	2.8E-02	3.3E-02	3.8E-02	4.2E-02	4.6E-02	5.2E-02	5.7E-02	5.8E-02	6.3E-02	6.9E-02	7.2E-02	7.4E-02	7.7E-02
25	4.1E-03	7.9E-03	1.2E-02	1.5E-02	1.8E-02	2.1E-02	2.7E-02	3.2E-02	3.6E-02	4.0E-02	4.4E-02	5.0E-02	5.5E-02	5.6E-02	6.0E-02	6.6E-02	6.9E-02	7.1E-02	7.3E-02
26	3.9E-03	7.7E-03	1.1E-02	1.4E-02	1.8E-02	2.1E-02	2.6E-02	3.1E-02	3.5E-02	3.9E-02	4.2E-02	4.8E-02	5.2E-02	5.3E-02	5.8E-02	6.3E-02	6.6E-02	6.8E-02	7.0E-02
27	3.8E-03	7.4E-03	1.1E-02	1.4E-02	1.7E-02	2.0E-02	2.5E-02	3.0E-02	3.4E-02	3.7E-02	4.1E-02	4.6E-02	5.0E-02	5.1E-02	5.5E-02	6.0E-02	6.3E-02	6.4E-02	6.6E-02
28	3.7E-03	7.1E-03	1.0E-02	1.3E-02	1.6E-02	1.9E-02	2.4E-02	2.8E-02	3.2E-02	3.6E-02	3.9E-02	4.4E-02	4.8E-02	4.9E-02	5.3E-02	5.7E-02	6.0E-02	6.1E-02	6.3E-02
29	3.5E-03	6.9E-03	1.0E-02	1.3E-02	1.6E-02	1.8E-02	2.3E-02	2.7E-02	3.1E-02	3.4E-02	3.7E-02	4.2E-02	4.6E-02	4.7E-02	5.0E-02	5.5E-02	5.7E-02	5.8E-02	6.0E-02
30	3.4E-03	6.6E-03	9.7E-03	1.2E-02	1.5E-02	1.8E-02	2.2E-02	2.6E-02	3.0E-02	3.3E-02	3.6E-02	4.0E-02	4.4E-02	4.5E-02	4.8E-02	5.2E-02	5.4E-02	5.5E-02	5.7E-02
31	3.3E-03	6.4E-03	9.3E-03	1.2E-02	1.5E-02	1.7E-02	2.1E-02	2.5E-02	2.9E-02	3.2E-02	3.4E-02	3.9E-02	4.2E-02	4.3E-02	4.6E-02	4.9E-02	5.1E-02	5.3E-02	5.4E-02
32	3.2E-03	6.2E-03	9.0E-03	1.2E-02	1.4E-02	1.6E-02	2.1E-02	2.4E-02	2.7E-02	3.0E-02	3.3E-02	3.7E-02	4.0E-02	4.1E-02	4.4E-02	4.7E-02	4.9E-02	5.0E-02	5.1E-02
33	3.1E-03	6.0E-03	8.7E-03	1.1E-02	1.4E-02	1.6E-02	2.0E-02	2.3E-02	2.6E-02	2.9E-02	3.1E-02	3.5E-02	3.8E-02	3.9E-02	4.2E-02	4.5E-02	4.6E-02	4.7E-02	4.8E-02
34	3.0E-03	5.7E-03	8.3E-03	1.1E-02	1.3E-02	1.5E-02	1.9E-02	2.2E-02	2.5E-02	2.8E-02	3.0E-02	3.4E-02	3.7E-02	3.7E-02	4.0E-02	4.2E-02	4.4E-02	4.5E-02	4.6E-02
35	2.9E-03	5.5E-03	8.0E-03	1.0E-02	1.3E-02	1.5E-02	1.8E-02	2.1E-02	2.4E-02	2.7E-02	2.9E-02	3.2E-02	3.5E-02	3.5E-02	3.8E-02	4.0E-02	4.2E-02	4.2E-02	4.3E-02
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37	2.7E-03	5.1E-03	7.5E-03	9.6E-03	1.2E-02	1.3E-02	1.7E-02	2.0E-02	2.2E-02	2.4E-02	2.6E-02	2.9E-02	3.2E-02	3.2E-02	3.4E-02	3.6E-02	3.7E-02	3.8E-02	3.8E-02
38	2.6E-03	5.0E-03	7.2E-03	9.2E-03	1.1E-02	1.3E-02	1.6E-02	1.9E-02	2.1E-02	2.3E-02	2.5E-02	2.8E-02	3.0E-02	3.0E-02	3.2E-02	3.4E-02	3.5E-02	3.6E-02	3.6E-02
39	2.5E-03	4.8E-03	6.9E-03	8.9E-03	1.1E-02	1.2E-02	1.5E-02	1.8E-02	2.0E-02	2.2E-02	2.4E-02	2.7E-02	2.8E-02	2.9E-02	3.0E-02	3.2E-02	3.3E-02	3.4E-02	3.4E-02
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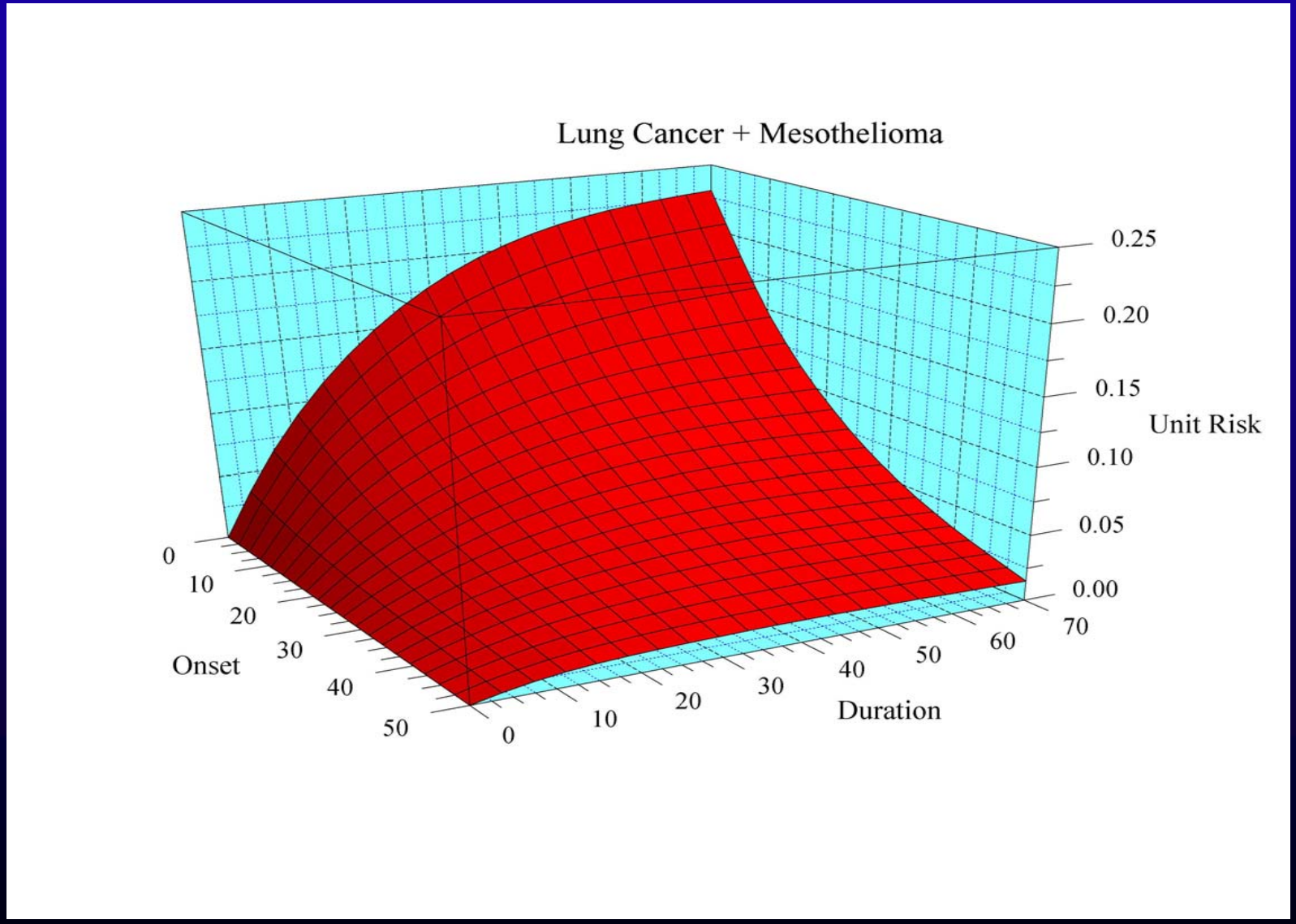
45	1.9E-03	3.7E-03	5.4E-03	6.9E-03	8.2E-03	9.5E-03	1.2E-02	1.3E-02	1.5E-02	1.6E-02	1.7E-02	1.9E-02	2.0E-02	2.0E-02	2.1E-02	2.2E-02	2.3E-02	2.3E-02	2.3E-02
50	1.5E-03	2.9E-03	4.1E-03	5.3E-03	6.3E-03	7.2E-03	8.7E-03	1.0E-02	1.1E-02	1.2E-02	1.3E-02	1.4E-02	1.4E-02	1.4E-02	1.5E-02	1.5E-02	1.5E-02	1.5E-02	1.6E-02

Unit Risks for Continuous Exposures: Function of Age at Onset & Exposure Duration



Agency Activities in Asbestos
Risk Assessment

- OSWER Risk Methodology
- IRIS Cancer Reassessment
  - IRIS non-cancer assessment
- Implementation support for framework
  - Training
  - Uncertainty analysis
  - Quality Assurance
    - Performance evaluation samples
    - SOPs for analysis

Technical Support Available from TRW Asbestos Committee

Co-Chairs:

- Arnold Den – Region 9
- Jim Konz – OSRTI
- Mark Maddaloni – Region 2

- All 10 Regions
- OSWER
- ERT
- ORD
- OEM
- OAQPS
- ATSDR
- OPPTS
- OECA

e-mail: asbestoshelp@epa.gov
TRW Hotline: 1-866-282-8622