EPA
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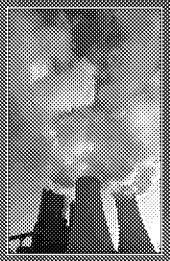
Environmental Protection
Agency

Translating Epidemiology into Action at EPA



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Office of Research and Development
National Center for Environmental Assessment

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EPA United States Environmental Protection Agency

Disclaimer

The views expressed in this presentation are those of the author and do not necessarily represent the views or polices of the U.S. Environmental Protection Agency.

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My Background

- BS, Biology (Allegheny College, Meadville, PA)
- US Peace Corps (Central America)
- MSPH, Environmental Health (Tulane University)
- PhD, Environmental Health (Colorado State University)
- Post-Doc, Environmental Epidemiology (UNC Chapel Hill)
- US EPA, Environmental Epidemiology (RTP, NC)

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Translating Epidemiology into Action at EPA
Overview

1. Risk Assessment – Paradigm and Definitions
2. Overview of Reference Values and Regulatory Standards
3. Examples of How Epidemiology Informs Reference Values and Regulatory Standards
4. Using Epidemiology in Benefits Analysis

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1. RISK ASSESSMENT PARADIGM

The field of RA can cover almost any aspect of life.

The term risk assessment is used in multiple contexts:
Engineering/structural
Financial/business
Security – vulnerability and threat assessment
Ecological
Human health
Physical injury
Radiation
Microbial
Chemical

And because risk assessment is contextual, the definition can vary by context. The context of this course is human health risk assessment, primarily focused on chemical risk assessment, and so the definitions that we will discuss are presented from this perspective.

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EPA Definition of Risk Assessment

Risk assessment:

Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants

From EPA's "Terms of Environment" Glossary

This is a general definition included in EPA's "Terms of Environment" glossary, so it is a non-technical definition used to communicate in plain language what risk assessment is.
It says, "Risk assessment is a qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants."
How does this compare with definitions the class created earlier?
An important concept to understand is that "risk" typically refers to the probability, or likelihood, that something might happen in the future. From the Terms of the Environment glossary, risk is "a measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard."
An evaluation of the current rate of disease within a population is not risk assessment; this is better described as epidemiology.
It is also important to know that risk assessment is used as a verb describing the process and also as a noun, describing the document that results from doing a risk assessment. In this course, we will typically use risk assessment as a verb.
For instructor reference:
This is a periodically-updated glossary of common terms; it can be found at http://www.epa.gov/glossary/.
Terms of Environment" defines in non-technical language the more commonly used environmental terms appearing in EPA publications, news releases, and other Agency documents available to the general public, students, the media, and Agency employees. The definitions do not constitute the Agency's official use of terms and phrases for regulatory purposes, and nothing in this document should be construed to alter or supplant any other federal document. Official terminology may be found in the laws and related regulations as published in such sources as the Congressional Record, Federal Register, and elsewhere.

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EPA's Definition of Risk Assessment

Risk assessment is the evaluation of scientific information on:

- the hazardous properties of environmental agents,
- the dose-response relationship, and
- the extent of human exposure to those agents.

The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree.

From EPA's Glossary of IRIS Terms

Hazard Identification

Dose-response Assessment

Exposure Assessment

Risk Characterization

A second, expanded definition of risk assessment can be found in EPA's Glossary of IRIS Terms. We're presenting this definition because IRIS is the focus of many of the courses to come in this series.
IRIS is EPA's Integrated Risk Information System; it is an important data base of toxicity information that NCEA developed and maintains.
This definition is based on the 4 components of the risk assessment paradigm developed by the National Research Council or NRC.

Pause to let class read the definition on the slide.
Risk assessment, in terms of human health, is the evaluation of scientific information on:
the hazardous properties of environmental agents (This is hazard identification, and IRIS assessments include hazard identification.),
the dose-response relationship (This is dose-response assessment and is also included in IRIS assessments.), and
the extent of human exposure to those agents (This is exposure assessment.).
The product of the risk assessment is a statement regarding the probability that populations or individuals so exposed will be harmed and to what degree (This is the risk characterization component of the National Research Council's paradigm). Risk characterization synthesizes the information collected and evaluated in the other three steps.

An analogous and similar (but not identical) definition exists for ecological risk assessment.
There is variation among federal agencies regarding the conduct of RA, but the overarching frameworks that Agencies use are based on the NRC paradigm. Details can differ based on statutory requirements and history of practice within the agency.

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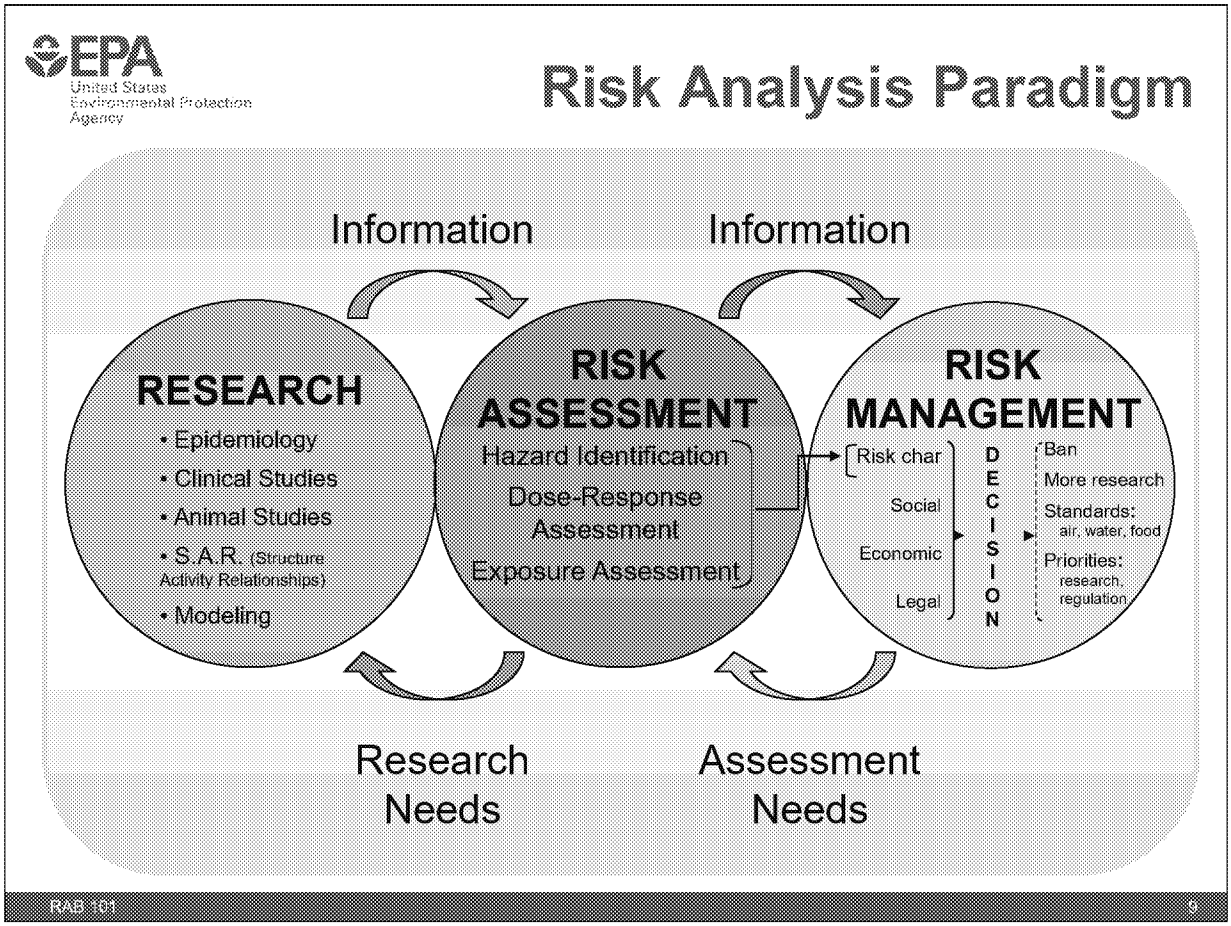
Brief History of Human Health Risk Assessment at EPA

- 1970: EPA established
- 1975: First EPA chemical assessment (vinyl chloride)
- National Research Council (NRC) publications on risk assessment
  - 1983: *Managing the Process* – the "Red Book"
  - 1989: *Improving Risk Communication*
  - 1994: *Science and Judgment* – the "Blue Book"
  - 1996: *Understanding Risk*
  - 2007: *Toxicity Testing in the 21st Century*
  - 2008: *Phthalates and Cumulative Risk Assessment*
  - 2009: *Science and Decisions* – the "Silver Book"

Brief History of Human Health Risk Assessment
This is not a comprehensive history but rather an overview of some key events in the timeline of chemical, human health risk assessment as it relates to EPA.
EPA was established in 1970.
EPA completed its first risk assessment document in December 1975.
Reports of cases of liver cancer (many resulting in death) in workers at vinyl chloride facilities were reported in the media in the early 1970s. Some cases of angiosarcoma were reported in people who lived in the vicinity of facilities producing vinyl chloride.
OSHA lowered permissible levels protecting workers, and EPA assessed the need to limit ambient emissions of vinyl chloride from these facilities.
EPA published the "Quantitative Risk Assessment for Community Exposure to Vinyl Chloride."
Followed in 1976 by "Interim Procedures and Guidelines for Health Risk and Economic Impact Assessments of Suspected Carcinogens" published by EPA Administrator (these were not formal guidelines or policy, but were the beginnings of such guidelines)
As a scientific field, risk assessment continued to evolve – for example, the Society for Risk Analysis (SRA) published the first issue of Risk Analysis in 1981.
Then, between 1983 and 2009, the National Research Council (a part of the National Academy of Sciences) published several documents that are key to risk assessment.
The first book, published in 1983 was titled Risk Assessment in the Federal Government: Managing the Process. You may hear it referred to as the "Red Book" because of the color of its cover.
NRC was commissioned by Congress to prepare this set of recommendations
Book contains definitions and fundamental processes still in use today
This book introduced the risk assessment paradigm with its four traditional components:
Hazard Identification
Dose-response Assessment
Exposure Assessment
Risk Characterization
1994 - Science and Judgment in Risk Assessment, aka the "Blue Book"
Also commissioned by Congress (via Clean Air Act)

In part, a follow-up to the Red Book, but with specific emphasis on EPA's scientific methods
2009 - Science and Decisions: Advancing Risk Assessment, aka the "Silver Book"
Discusses the planning and scoping principles of risk assessment along with stakeholder involvement, with EPA in mind
Other NRC publications on risk assessment include:
1989: Improving Risk Communication
1996: Understanding Risk
2007: Toxicity Testing in the 21st Century
2008: Phthalates and Cumulative Risk Assessment



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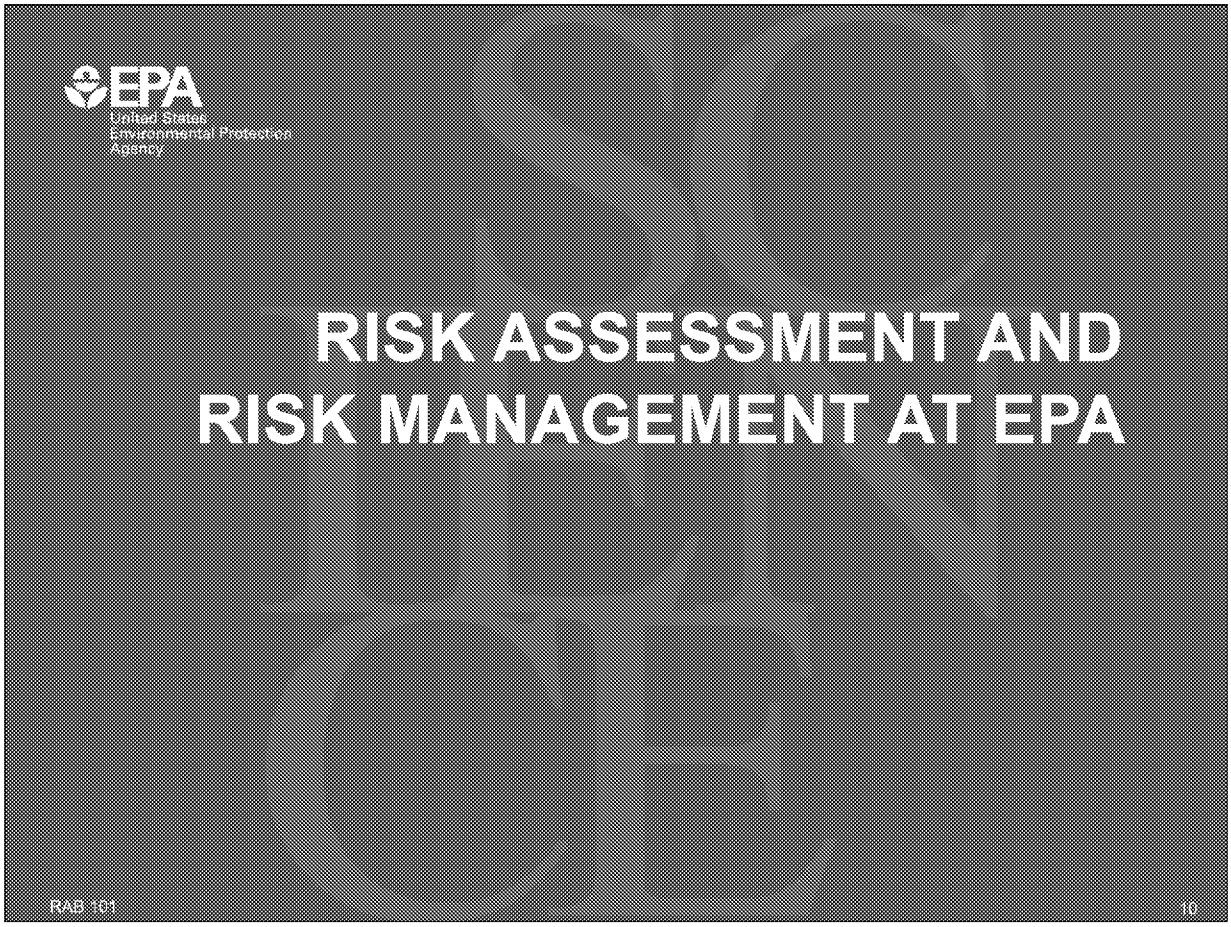
Risk assessment can be viewed as part of a broader "risk analysis" paradigm. The other two components are:
Research including epidemiology research, clinical studies, animal studies, investigations into structure activity relationships and modeling.
Risk management which covers regulatory (or other) decision-making.
Some people also include risk communication which covers effectively communicating the results of risk assessment and the policy implications of risk management decisions.
This course is focused on risk assessment, which is primarily concerned with scientific evaluation
For IRIS chemical managers, particular emphasis on hazard identification and dose-response assessment.
Within the risk assessment circle, the three of the four basic components of risk assessment are listed (according to the 1983 NRC red book).
Hazard Identification
Dose-response Assessment
Exposure Assessment
Risk Characterization is shown in the Risk Management circle.
Many groups who have defined risk assessment include these 4 components (or some variation) in the definition. (Did the class come up with these? If so, acknowledge.)
Although the 3 circles are more general than just human health risk assessment, the 4 components of risk assessment are specific to human health RA.
Ecological RA has a slightly different outline and groups dose-response (effect) and exposure assessment into an "Analysis Phase."



Now that we all have a common vocabulary to use to talk about risk assessment, how does EPA's Office of Research and Development, and specifically, the National Center for Environmental Assessment, contribute to EPA's risk assessment?

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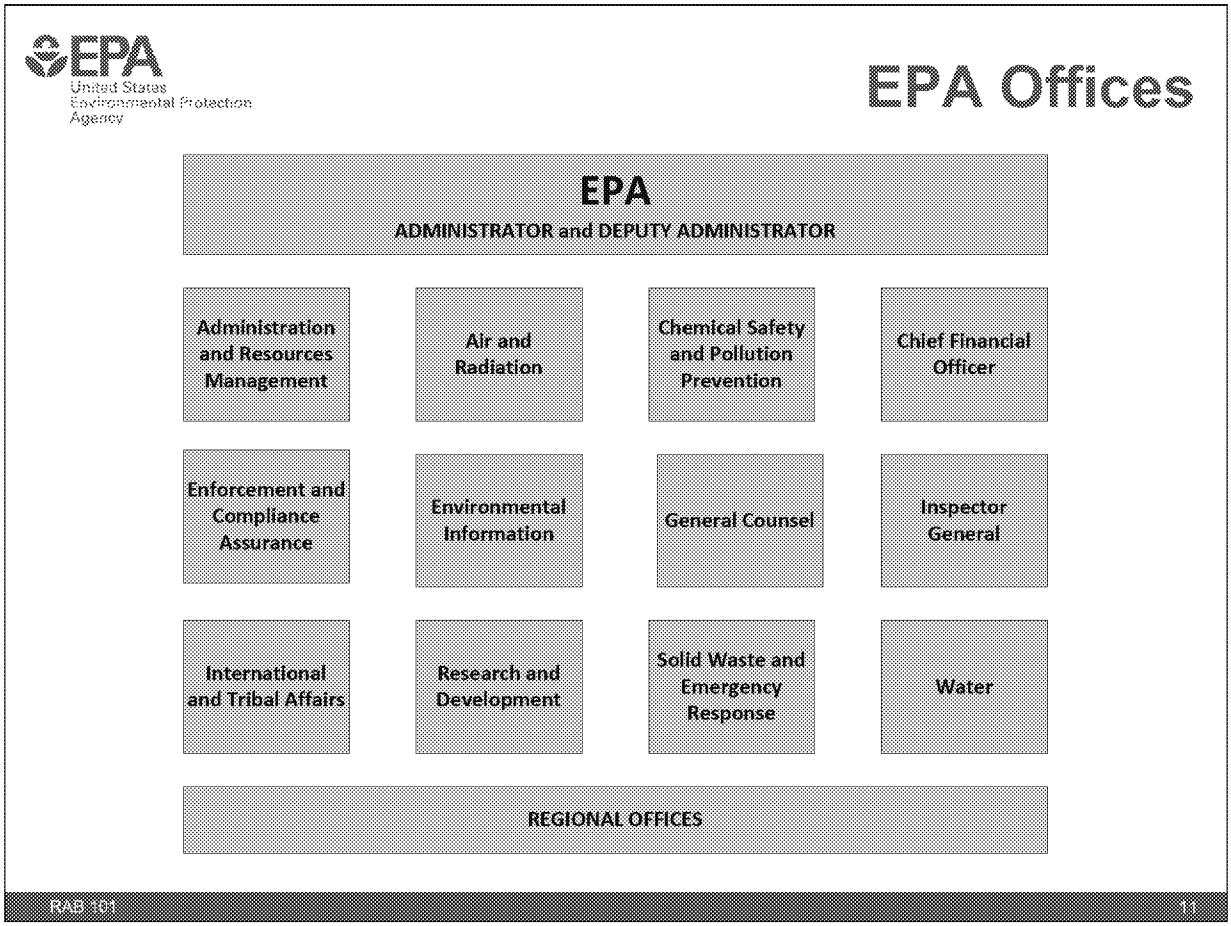
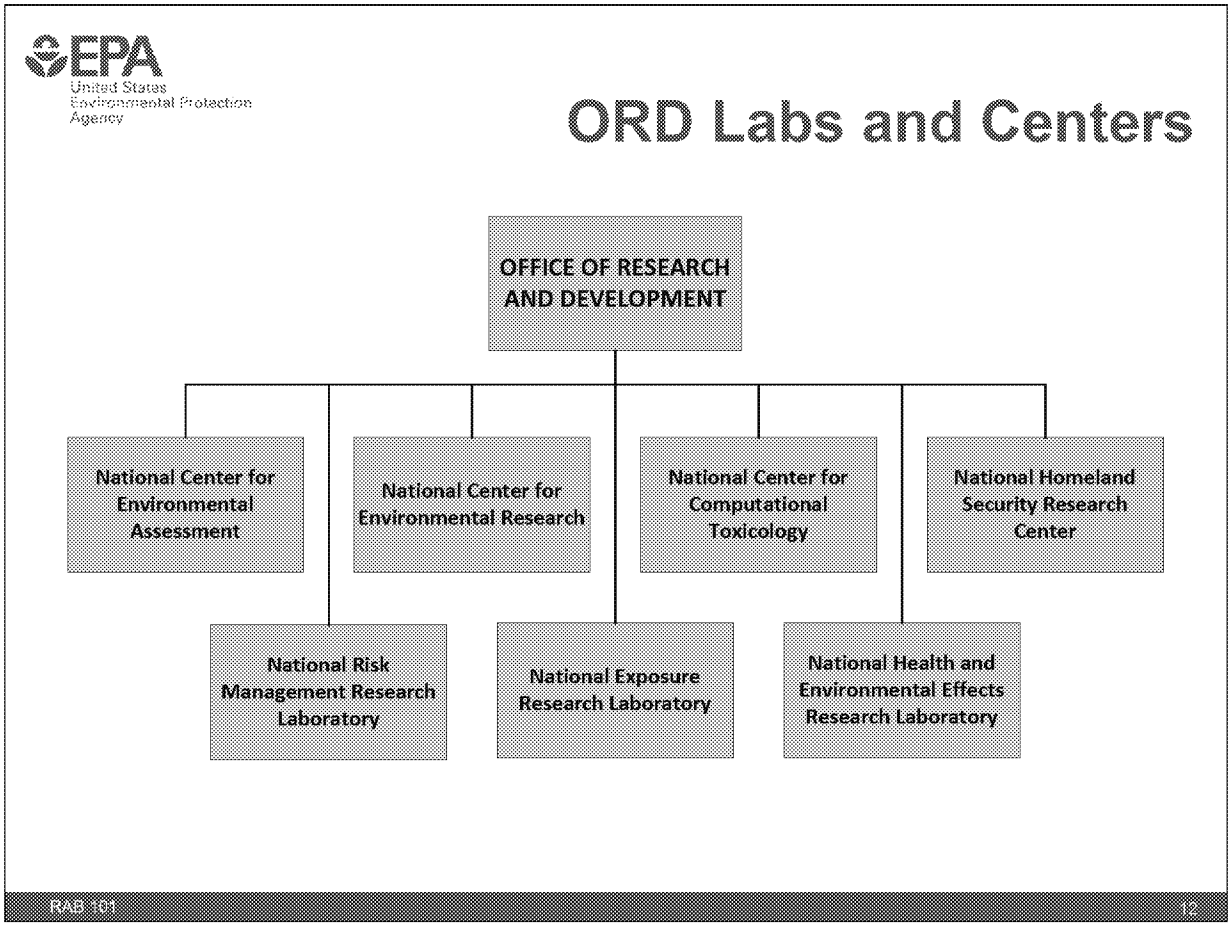


First, we need to understand where the Office of Research and Development fits in to EPA. EPA is divided into 12 offices that develop programs and 10 regional offices that help to implement EPA's programs in the states. ORD is highlighted in blue in this organizational chart.
The Office of Air and Radiation implements the Clean Air Act and performs risk assessments with NCEA's help to set the National Ambient Air Quality Standards for criteria air pollutants.
The Office of Chemical Safety and Pollution Prevention implements the Federal Insecticide, Fungicide, and Rodenticide Act as well as the Toxic Substances Control Act each of which requires that EPA weigh the risks of pesticides and other chemicals against their benefits.
The Office of Solid Waste and Emergency Response develops guidelines for the disposal of hazardous waste and underground storage tanks based on risk assessments.
The Office of Water implements the Clean Water Act, the Safe Drinking Water Act, and the Marine Protection, Research, and Sanctuaries Act (Ocean Dumping Act) and conducts risk assessments of chemicals in order to set or recommend safe levels for people and fish, plants, and wildlife.
The 10 regional offices are responsible for implementing clean water regulations, responding to hazardous waste emergencies, handling enforcement and compliance, and in general implementing EPA programs in the states. They conduct site-specific risk assessments under the Superfund program.



There are 7 parts of ORD.
Four of them are labs doing primary research:
National Risk Management Research Laboratory (NRMRL)
National Exposure Research Laboratory (NERL)
National Health and Environmental Effects Research Laboratory (NHEERL), and
National Homeland Security Research Center (NHSRC)
The National Center for Computational Toxicology (NCCT) is basically a lab with an emphasis on doing primary research (except typically using computers, not in a traditional lab space).
The National Center for Environmental Research is also focused on primary research, but is concerned with the work done by extramural (or non-EPA) labs.
The research conducted in the labs supports risk assessment.
But NCEA is different. [as explained in the next slide]

For instructor reference:
National Center for Environmental Research (NCER) supports environmental research in the academic community that complements ORD's in-house research.
National Center for Computational Toxicology (NCCT) applies mathematical tools to help the Agency with data priorities, reporting requirements, and interpretation.
National Risk Management Research Laboratory (NRMRL) investigates ways to prevent/reduce health and environmental risks from pollution.
National Exposure Research Laboratory (NERL) provides information to improve the accuracy of EPA's exposure and risk assessments of environmental stressors.
National Health and Environmental Effects Research Laboratory (NHEERL) focuses on research into the adverse effects of contaminants and environmental stressors.
National Homeland Security Research Center focuses on efforts to improve the nation's capability to protect from and respond to terrorist attacks on our water and wastewater infrastructure AND on efforts to improve the nation's capability to respond to terrorist attacks affecting buildings and the outdoor environment.

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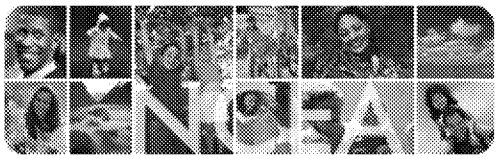
National Center for Environmental Assessment

Resource center for human health and ecological risk assessment

NCEA:

- Develops guidelines, methodologies, and training
- Creates tools and databases
- Integrates and applies ORD- and extramural-generated research
- Performs risk assessments
- Consults with EPA programs, regions, and decision makers

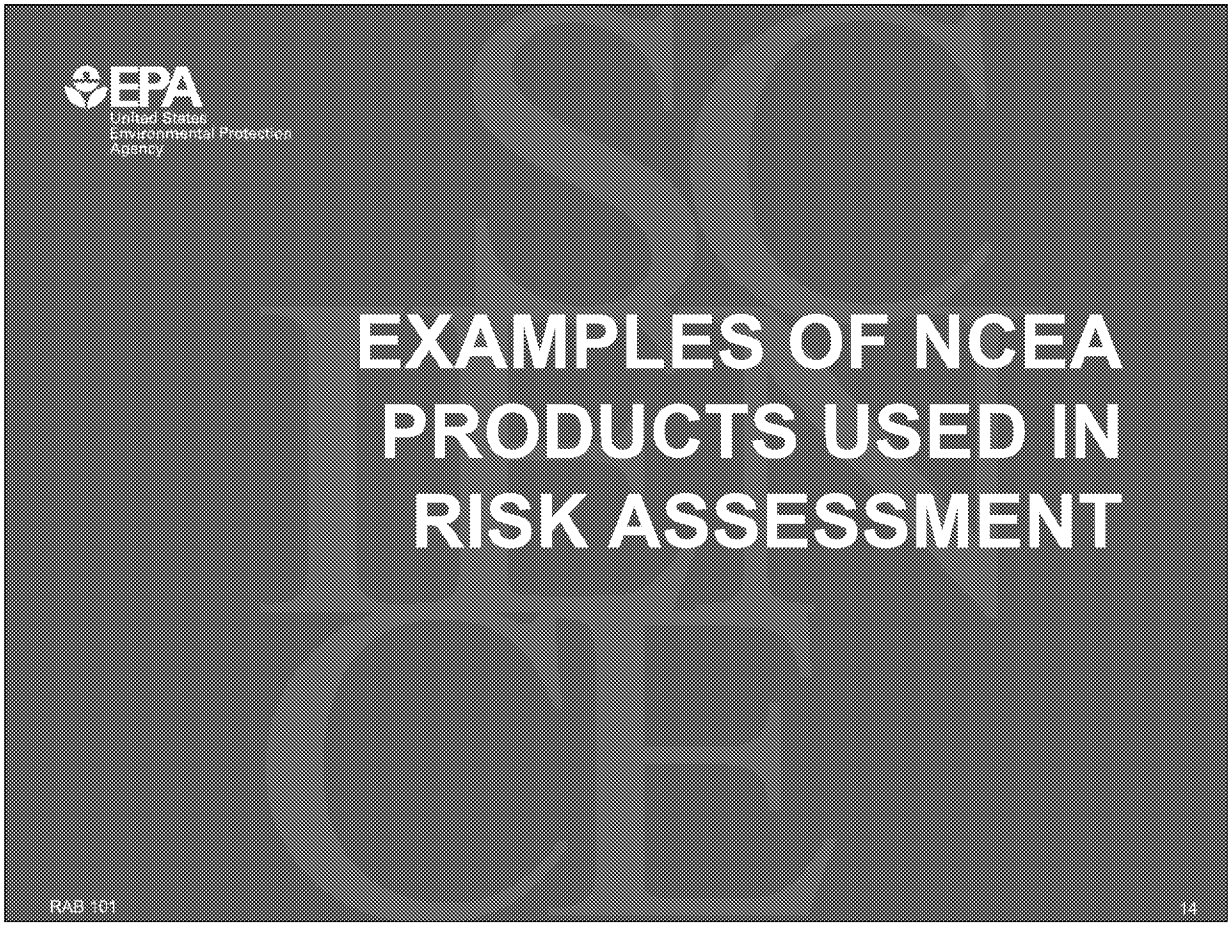


The mission of NCEA is to provide guidance about how pollutants may impact human health and the environment. As part of ORD, EPA´s National Center for Environmental Assessment (NCEA) serves as the national resource center for human health and ecological risk assessment.

NCEA develops new methods for risk assessment, and applies those methods to a variety of issues the Agency faces. This includes developing guidelines, methodologies, and training. Later in this course series we will talk about BMD software, one of the tools developed by NCEA, and we'll focus on IRIS, one of the databases created by NCEA.

NCEA serves as a key link between researchers within ORD and EPA decision makers and integrates and applies research generated within ORD and also research generated outside of the Agency. One very visible way NCEA integrates and applies research is through the risk assessments it performs.

NCEA plays an important role as a consultant on the use of science in environmental policymaking by interfacing with other EPA Program Offices, EPA Regional Offices, and other decision-makers and stakeholders.



The following are some examples of NCEA products used in risk assessment.

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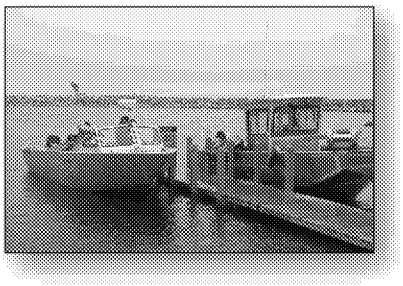
IRIS Values Used in Generation of Fish Advisories



- IRIS includes an RfD for methylmercury
- RfD combined with exposure factors and contaminant concentrations
- Result is general advice about fish consumption and location-specific advisories

EPA uses the IRIS Reference Dose (RfD) for Methylmercury, a common contaminant found in fish, to develop fish consumption advisories.
EPA used the RfD from IRIS along exposure factors such as fish meal size and consumer body weight in conjunction with measured contaminant concentrations in the fish tissue to calculate monthly fish consumption limits for non-cancer endpoints. The advisories range from general advice about what kinds of fish to avoid and about how much fish is safe to consume to location-specific advisories for lakes and other waterbodies across the country. Resulting recommendations include to avoid high-mercury fish (like shark and swordfish) and to limit meals of low-mercury fish (e.g. shrimp, salmon) to about two per week, fewer if mercury content unknown.
The RfD is used in a similar way to set local advisories about the safety of fish caught in local lakes, rivers, and coastal areas.

For instructor reference:
RfD is the daily ingested dose someone can be exposed to over a lifetime without deleterious effects.
Reference Dose (RfD): An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments. [Durations include acute, short-term, subchronic, and chronic and are defined individually in the IRIS glossary].

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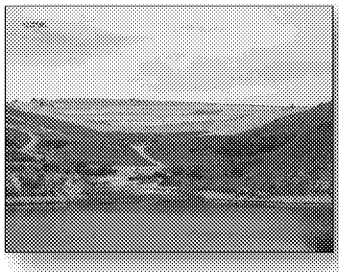
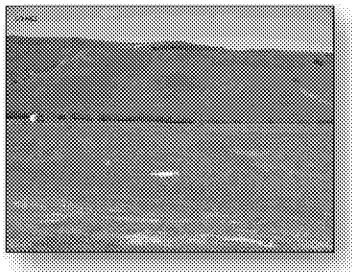
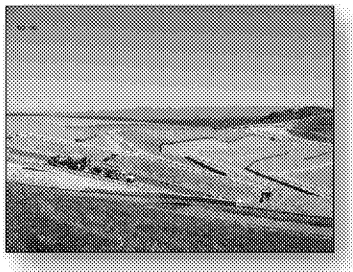
IRIS Values for Superfund

Casmalia Resources in Santa Barbara County, CA

- Former hazardous waste management facility
- Chemicals of concern include pesticides, solvents, acids (including hydrogen sulfide), PCBs, and heavy metals
- IRIS values support decisions about remedial actions including landfill covers, groundwater monitoring, and site improvements

IRIS values are used to help determine what levels clean up efforts at Superfund sites should achieve along with other factors (such as Best Available Control Technology or BACT) by risk managers.
For example contaminate levels at sites are compared to IRIS values, and if the levels are higher than IRIS values, then additional clean up is required.
The Casmalia Resources Superfund Site
From 1973 until 1989, the Casmalia Resources facility took in 5.6 billion pounds of waste including sludges, pesticides, solvents, acids, metals, caustics, cyanide, and nonliquid polychlorinated biphenyls (PCBs).
Contaminant levels in air, soil, surface water, and ground water in the nearby town and at the site were compared to existing EPA IRIS reference values. Hydrogen sulfide and acrolein (ah-cro-lee-un) were among the chemicals that needed to be cleaned up.
Based on these comparisons, remedial actions were selected including:
Capping the landfills designated for pesticides and solvents, heavy metals, caustics and cyanide, acids, and PCBs;
Installing and operating a ground water collection and treatment system;
Consolidating and managing waste water collection and containment impoundments; and
Implementing site improvements such as slope stabilization and minimizing the amounts of infiltrating rainwater.
The remedial actions chosen help ensure that the hazardous wastes disposed of at the site are stable and contained for a long time and that the hazardous wastes do not enter the ground water, air, or soil near the site.

Pictures left to right:
Landfill containing metals was capped in 2001.
A view of Casmalia Creek from the site.
After landfills are capped, they are hydroseeded to grow vegetation.

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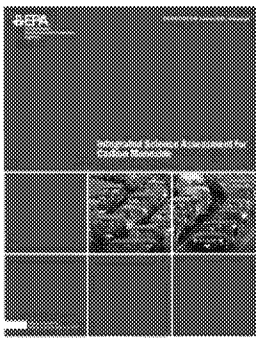
Integrated Science Assessments

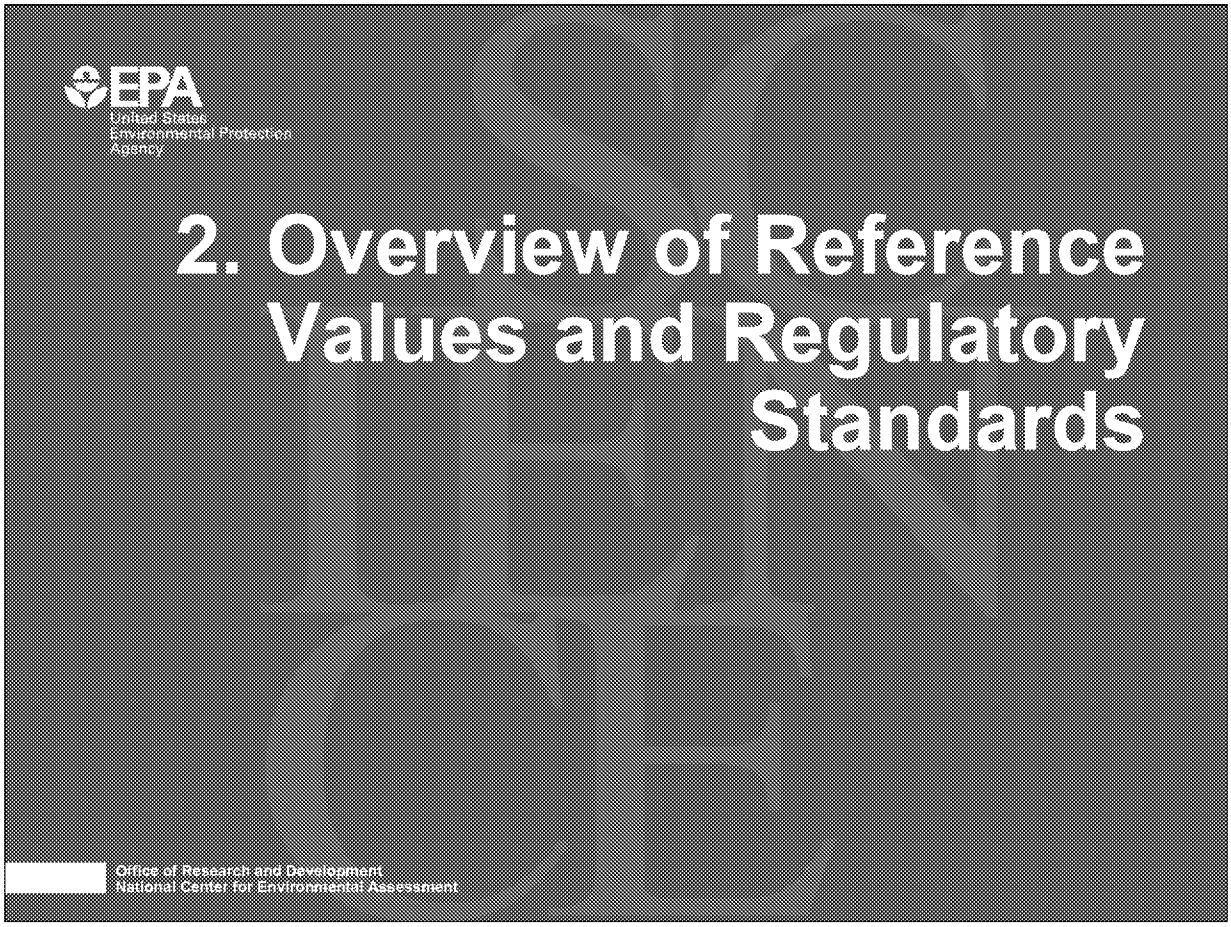
The ISA accurately reflects "the latest scientific knowledge useful in indicating the kind and extent of identifiable effects on public health which may be expected from the presence of [a] pollutant in ambient air." (Clean Air Act, Section 108, 2003)

ISA for Carbon Monoxide – January 2010

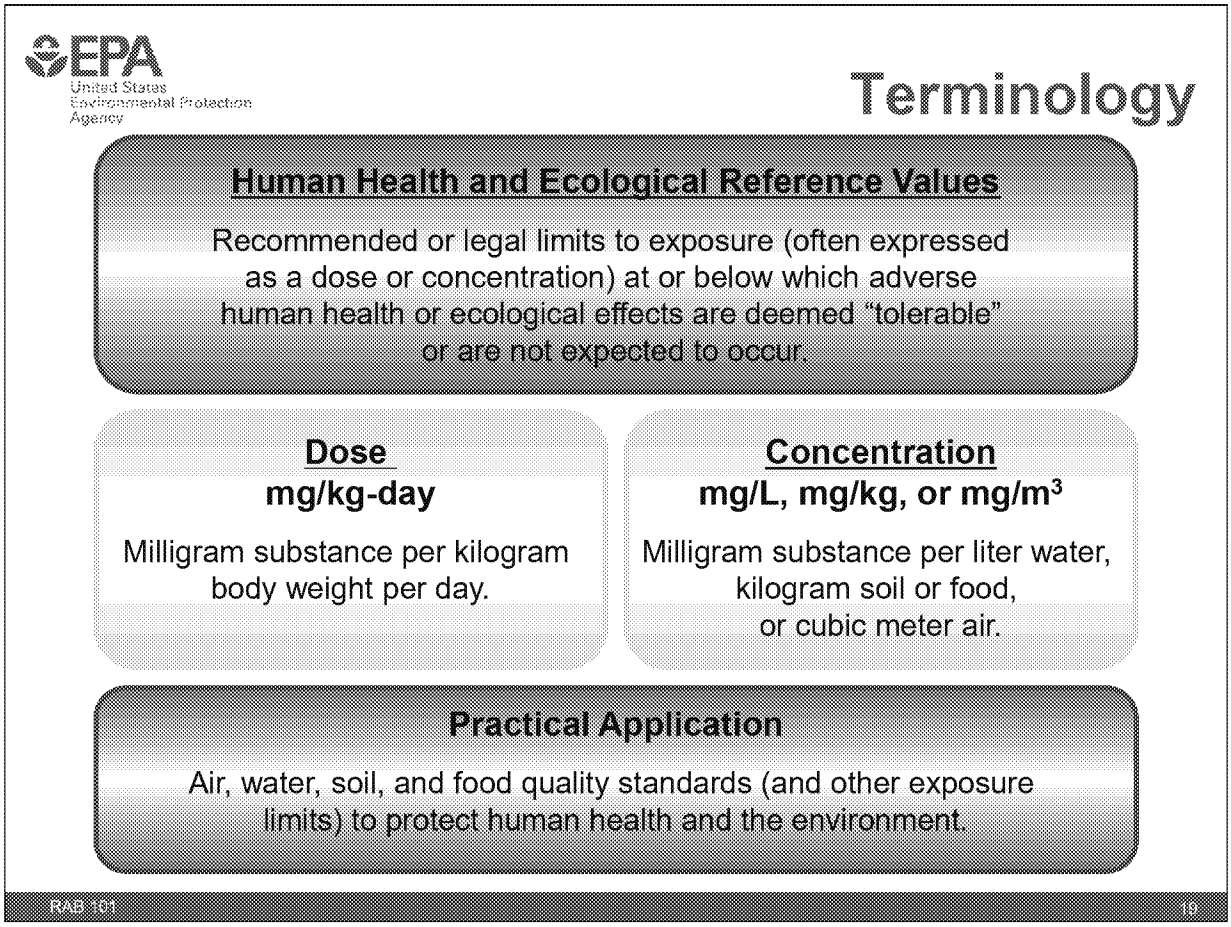
ISA states "that a causal relationship is likely to exist between relevant short-term CO exposures and cardiovascular morbidity."



The Clean Air Act requires EPA to set standards for six criteria air pollutants that are known to be harmful to people and the environment. These are the National Ambient Air Quality Standards (or NAAQS).
What are the six criteria air pollutants?
The NAAQS are reviewed every five years, and to begin this review, NCEA develops an Integrated Science Assessment or ISA. The ISA is intended to be a review and an evaluation of the most policy relevant science for the criteria air pollutant. ISAs are then used to support development of the that are developed by OAQPS (or the Office of Air Quality and Planning Standards within the Office of Air and Radiation).
ISAs potentially contain a collection of all the information needed to do the risk assessment. They have information on:
Sources of the pollutant;
Ambient concentrations and exposure;
Dosimetry, Pharmacokinetics, and Mode of Action;
Potential health Effects (e.g., cardiovascular, nervous system, birth outcomes, mortality);
Susceptible populations; and
Concentration- and dose-response relationships.
In January of 2010, NCEA finalized the ISA for carbon monoxide. The ISA states that there is likely to be a causal relationship between short term exposure and cardiovascular morbidity.
The results of this risk assessment will inform the risk management decision about whether or not to change the NAAQS for CO. Across the country, the average CO concentration decreased by 41% between 2001 and 2008 All monitored concentrations at locations all across the country were below the NAAQS for CO (8-hr average = 9 ppm, 1-hr average = 35 ppm).
For instructor reference:
There are 6 "criteria" pollutants regulated by NAAQS:
Carbon Monoxide
Lead
Nitrogen Dioxide
Ozone
Particulate Matter
Sulfur Dioxide



The following are some examples of NCEA products used in risk assessment.



Terminology

In this course, we will talk about What human health and ecological reference values are.

Very generally, reference values are chemical doses or exposure concentrations at or below which adverse health effects in a population are not expected to occur. When these reference values are not purely health-based, in that other factors are also considered in the development of the value, effects might occur, but the frequency and severity of these effects is deemed "tolerable." This concept is often referred to as "acceptable risk."

Among other factors, certain reference values might take into consideration the ability of measurement technology to detect a chemical at a concentration below what is expected to result in an adverse effect. If the technology cannot detect the chemical at this level, the reference value might be raised to the level at which the chemical can be reliably measured. As a result, this exposure limit might not be as conservative as a purely health-based value, but regulation and enforcement of the limit becomes feasible.

A chemical dose is commonly expressed as a quantity of a substance per kilogram of body weight averaged over 24 hours.

A chemical concentration in a specified environmental medium is commonly expressed as quantity of a substance per quantity of medium.

Though these are two of the most common metrics for expressing reference values, some reference values are expressed as proportion of the population estimated to be affected at a specified concentration.

Once developed, reference values are used in programmatic and site-specific risk assessments to specify a recommended or legal limit to chemical exposure or environmental contamination.

This is intended to protect a population from exposure to levels of chemicals in air, water, soil, or food that might result in adverse human health or ecological effects.

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Reference Values: Levels of Enforceability

Exposure Standards	Exposure Guidelines
Relatively few	Numerous
Mandated by statute and legally enforceable	Not legally enforceable
Rigid development process	Flexible development process
Developed by government agencies specified in statutes	Developed by many types of entities
Intended to protect health and the environment, but balances other considerations	Intended to protect human health and the environment

Reference Values: Levels of Enforceability

Not all limits to chemical exposure or environmental contamination that are derived from the risk assessment process are legally enforceable. In fact, most are simply recommended limits to human exposure, with relatively few limits mandated by a regulatory statute.

Regulatory Standards, as we've discussed, are developed to set legal limits for exposures to ensure "safe" levels for the general public or a subpopulation, but they are not completely health-based. For example, when considering alternative actions for a proposed programmatic rule, agencies generally consider human health risks across the alternatives in addition to other factors (e.g., socioeconomic impacts, environmental justice, available control technologies).

There are considerably fewer regulatory standards than non-enforceable guidelines. This generally occurs because:

there is a complex legal process for the development of a standard;

standards are less adaptable to specific scenarios than guidelines, largely because many other factors must be woven into the final standard; and

a statute specifies the agency required to develop the regulations, so only the specified entities cannot develop the standard.

The takeaway message is that legally enforceable standards balance health effects with a range of other considerations to establish what is termed an "acceptable" risk level.

Guidelines are developed specifically to protect human health or the environment based solely on toxicological data. Although they are not legally enforceable, these reference values sometimes represent levels that a federal or state entity is prepared to regulate, if necessary. As a result, guidelines are often the health-based starting point for developing regulatory standards.

There are many more recommended exposure guidelines than regulatory standards. This generally occurs because:

exposure guidelines can be adapted to specific scenarios (e.g., duration, population, exposure media) to be protective of human health in these specific scenarios;

they can be developed by entities that are non-regulatory – that is, government offices not mandated to carry out a statute; state, local, and tribal governments; not-for-profit organizations); and

they do not need to be adapted to consider economic, engineering, or regulatory limitations to achieve the recommended dose or exposure limit, which differs from regulatory standards.

The take-away message is that these values are health-based values that can be derived by any entity using only toxicological data as the basis for the recommended level.

- Pose this question to the participants: Now that we've gone over the criteria for what defines a standard, are there any

values that we brought up in our class discussion that you now believe not to be standards?

- On the next slide is a list of the major regulatory standards developed by the Federal Government that set legal limits to chemical exposure. Let's see how many we identified in our class discussion.

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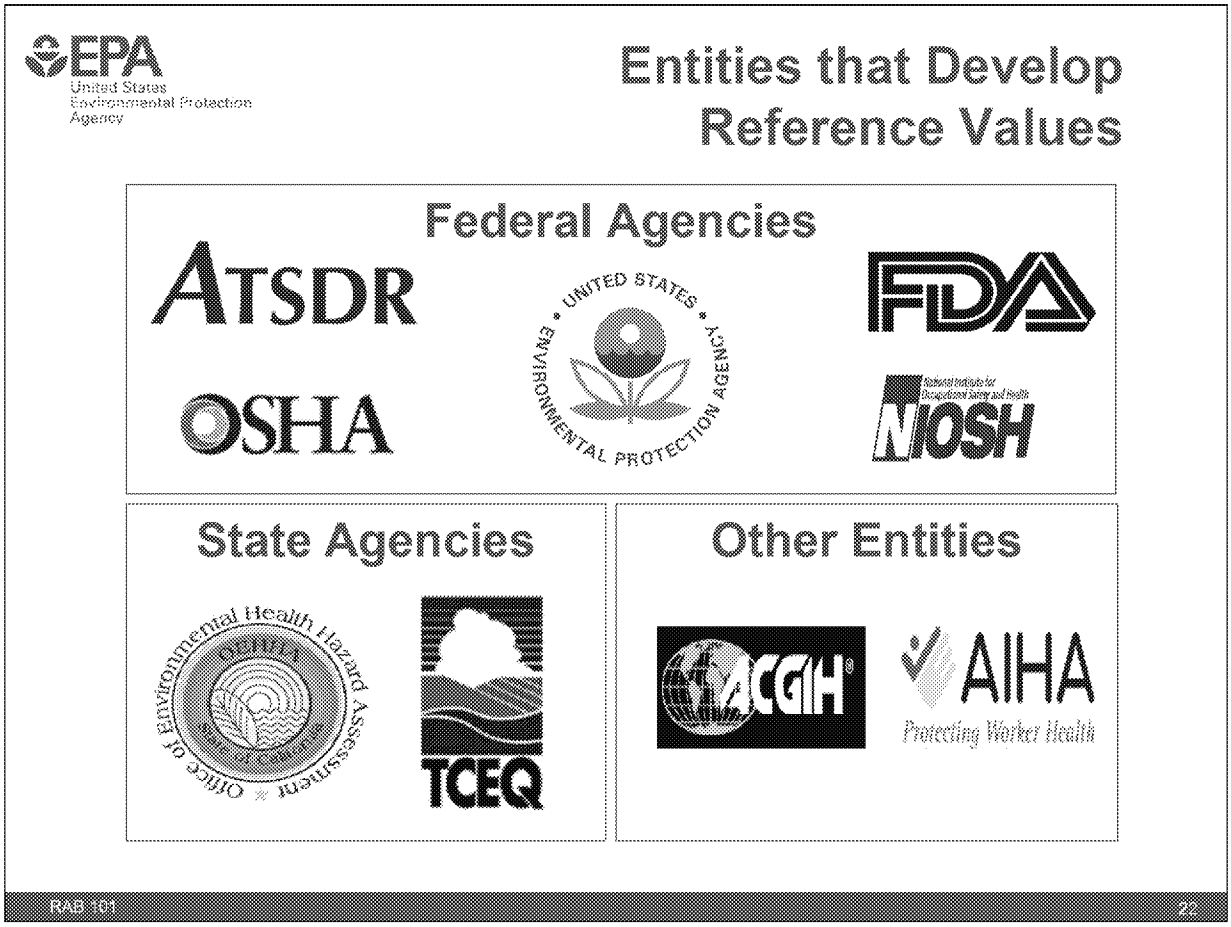
Exposure Standards

Medium	Standard	Regulated Contaminants	Regulatory Authority
Air	National Ambient Air Quality Standards (**NAAQS**)	6 Criteria Pollutants in ambient air	EPA, as mandated by the Clean Air Act
	Permissible Exposure Limits (**PELs**)	~500 contaminants in workplace air	OSHA, as mandated by the Occupational Safety and Health Act
Water	Maximum Contaminant Levels (**MCLs**)	90 chemical, microbiological, radiological, and physical contaminants in drinking water	EPA, as mandated by the Safe Drinking Water Act
Food	Maximum Residue Limits (**MRLs**)	Hundreds of pesticide chemicals in food and feed commodities	EPA, as mandated by the Federal Food, Drug, and Cosmetics Act, as amended by the Food Quality Protection Act

Although this table is not an exhaustive list of exposure standards developed by federal agencies, it is a large subset, demonstrating just how infrequently major exposure standards are developed.
To briefly review what is on the slide, these four standards are some of the most well-known and widely applied standards in the United States.
National Ambient Air Quality Standards, or NAAQS, have been developed for only 6 principal pollutants (called criteria pollutants) in ambient air.
Permissible Exposure Levels, or PELs, on the other hand, have been developed for over 500 contaminants in workplace air.
Maximum Contaminant Levels, or MCLs, have been developed for 90 contaminants in drinking water, but this does not apply to surface water, which we will also discuss later in this course.
Notice that no standards have been set for soil – due in part to the difficulty of establishing a standard for such a complex and variable medium.
Last on this list, Maximum Residue Limits, or MRLs, are "tolerances" set for pesticide residues in food. Over 450 pesticides have been assigned tolerances or tolerance exemptions.
Notice on this slide that most of these exposure standards have been developed by the U.S. Environmental Protection Agency, with one developed by the U.S. Department of Labor's Occupational Safety and Health Administration. As we discussed in the previous slide, only federal, state, or tribal governments can pass legally enforceable standards.



We started this course with a discussion of legally enforceable standards to establish a context for human health and ecological reference values using well-known examples. We'll now depart from the discussion of standards and focus on reference values as a whole, including

More detailed discussion on entities that derive them and why

What information is needed to develop a reference value, and

How these values can be applied.

As you can see, a number of federal agencies other than EPA and OSHA, as well as state agencies, do develop reference values; however, most are recommended limits to exposure, rather than legal standards. Scientific Organizations not associated with a government agency can also develop reference values as recommended limits to exposure. For example,

The American Conference of Governmental Industrial Hygienists, or ACGIH, is a not-for-profit scientific association that develops human health reference values to enable industrial hygienists to make decisions regarding the relative safety of exposure to various chemical substances and physical agents found in the workplace.

Because so many organizations develop reference values, there is a need to centralize and prioritize these values for risk assessment and management purposes.

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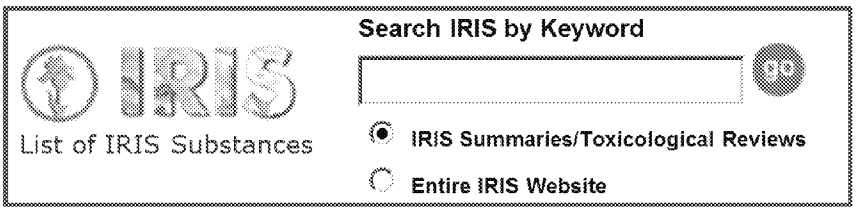
IRIS – EPA's Preferred Reference Values



EPA's Integrated Risk Information System (IRIS)

- Supports EPA's programmatic actions and other entities.
- Intended to be the highest-quality, science-based toxicity reference values.
- Contains peer-reviewed, Agency-derived values.
- Derived for specific chemical substances.
- Based on review of all relevant toxicity, toxicokinetic, and mode of action (MOA) information.

In response to a growing demand for consistent information on substances for use in risk assessments, decisionmaking, and regulatory activities, EPA's National Center for Environmental Assessment, or NCEA (within the Office of Research and Development), develops human health reference values that are included in an Integrated Risk Information System, or IRIS. These IRIS values are EPA's preferred values for risk assessment.

Such centralization of the development of these values at NCEA helps to:

include best science and peer review in the risk assessment process, and

reduce variability in risk assessments by providing other agencies, organizations, and regulated parties with standard toxicity reference values.

IRIS values have been derived for more than 540 chemical substances using the most relevant toxicological data.

 Next, we will discuss the specific components of a human health or ecological reference value that allow it to be applied within a certain exposure context.

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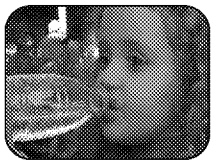
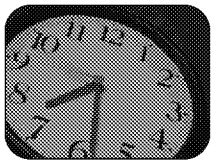
Exposure Specifications



Exposure Medium and Route

- Inhalation – air
- Oral – water, soil, food
- Dermal – soil, water, food, air



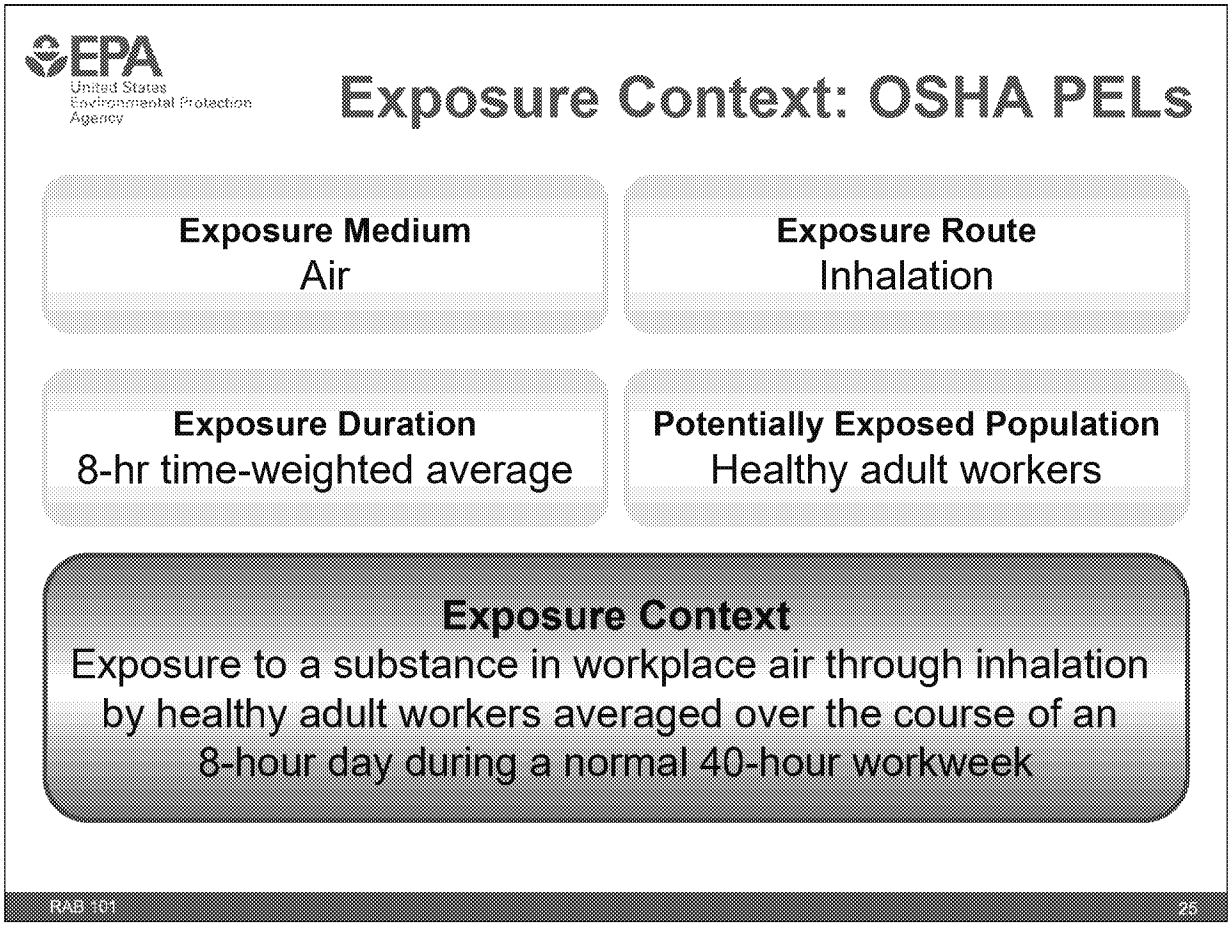
Exposure Duration

- Acute
- Short-term
- Longer-term
- Chronic (continuous)

Potentially Exposed Population

- Workers
- Emergency responders or victims
- Pregnant women
- Children or the elderly

Exposure Specifications
All reference values are developed using exposure specifications to establish or define the conditions and context in which they can be used most appropriately:
Where the chemical is found and how it enters the body are referred to as the exposure medium and route (these generally go hand-in-hand). For example
Where the medium is air, the route is generally inhalation
Where the medium is water, the route is generally oral
Where the medium is soil, the route is generally dermal
However, particles in air can settle on the skin, contaminated soil can be ingested, and water can be accidentally aspirated or can touch the skin during bathing, swimming, or other activities, so less direct routes are often investigated.
The time over which an individual or a population is exposed to a chemical is referred to as the exposure duration – EPA uses four general categories, but reference values can be developed for any specific duration. The EPA duration categories are
Acute
Short-term
Longer term (sometimes referred to as subchronic)
Long-term (also referred to as chronic)
Other entities might not use the same terminology in describing duration categories. For example, the CDC's Agency for Toxic Substances and Disease Registry, or ATSDR, uses only three general categories: short-term, intermediate, and long-term.
Those likely to be exposed to a chemical of interest are referred to as the potentially exposed population. Sometimes that means the general population, but risk assessors often focus on a particular subset of the population, such as
Healthy adult workers
Workers and citizens returning to sites contaminated during a hazardous substance release
Pregnant women and developing fetuses
Healthy children or the elderly



Exposure Context

Finally, an exposure context ties together the exposure medium, route, duration, and potentially exposed population to define the circumstances in which it is most appropriate for the reference value to be applied.
For example, OSHA PELs, which we introduced earlier as legally enforceable standards, are developed to protect workers against the health effects of exposure to hazardous substances in the workplace. So that these reference values can be used for evaluation and control purposes within this context, they were developed to incorporate the most applicable exposure specifications.
In this case, the most appropriate medium was determined to be air (although a skin designation is often provided for direct dermal contact with a chemical). The most appropriate exposure routes were therefore determined to be through inhalation of airborne particles or dermal uptake of substances on the skin. The most appropriate exposure duration was assumed to be a normal 8-hour workday in a normal 40-hour workweek, for which the exposure concentration is averaged over each 8-hour day. And because of the occupational setting, the potentially exposed population of interest is the healthy adult workers that would be present in the workplace over a 40-hr workweek.
Though we'll discuss the application of such reference values in more detail later in this course, the ability of risk assessors to tailor reference values to specific situations allows risk managers and decisionmakers to implement appropriate strategies to reduce or avoid exposures to harmful substances. In the case of PELs, these reference values are used to select appropriate control technologies and to engineer harmful substances out of a process, if possible, and if not, to provide the most appropriate level of personal protective and ventilation equipment.

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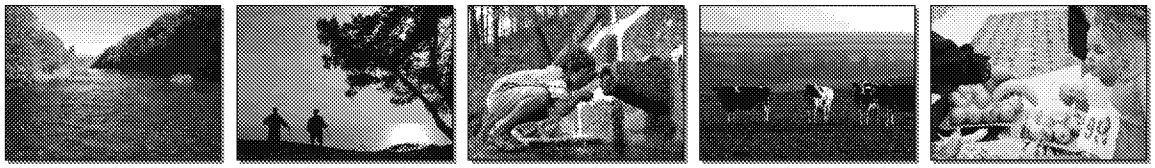
Ambient and General Public Values: Characteristics

- **Exposure Type:** Ambient
- **Duration:** Generally long-term
- **Medium:** Developed for air, water, and food
- **Enforceability:** Some are legally enforceable
- **Applicability:** Prevent harm from chemical exposures over the course of a lifetime; must protect sensitive subgroups
- **Adaptability:** Frequently developed for protection of human health and the environment



Exposure context: Must protect the general public and susceptible subpopulations (e.g., children, the elderly, those with compromised health).

Exposure Duration: generally developed for long-term, continuous exposure, but some acute values do exist.

Medium: Developed for air, water, and food exposure media and for inhalation, oral, and dermal routes of exposure.

Enforceability: General public values can be mandated under a regulatory statute, and therefore can be enforceable. However, many entities derive general public values simply as non-enforceable guidelines.

Applicability: To set exposure limits that inform risk characterization and risk management so that humans during daily life are protected from contaminants at level of no appreciable risk of harm.

Adaptability: Frequently developed for protection of human health and the environment.

General Public Values: IRIS

Guideline	Organization and Context
RfD Reference dose	Integrated Risk information System (IRIS) values are:
RfC Reference concentration	Developed to support hazard identification and dose-response assessment.
CSF Cancer slope factor	Used to characterize public health risks of a given substance in a given situation.
UR Unit Risk	Used to form the basis for risk-based decision-making, regulatory activities, and other risk management decisions.

IRIS includes EPA-derived guidelines for inhalation and oral routes of exposure.
IRIS values can be used in combination with exposure information to characterize the public health risks of a given substance in a given situation
Risk characterizations can then form the basis for risk-based decision-making, regulatory activities, and other risk management decisions designed to characterize and protect public health.
There are two general types of human health reference values in IRIS – noncancer and cancer.
For noncancer effects (or effects known or assumed to be produced through a nonlinear (possibly threshold) mode of action)
RfDs - Reference doses for oral exposure (ingestion)
RfCs – Reference concentrations for inhalation exposure
For cancer effects:
Cancer slope factors, sometimes called oral slope factors.
Oral and inhalation unit risks for carcinogenic effects.
For carcinogens, there also are descriptors that characterize the weight of evidence for human carcinogenicity in IRIS. Weight-of-evidence is a system used by the EPA for characterizing the extent to which the available data support the hypothesis that an agent causes cancer in humans.

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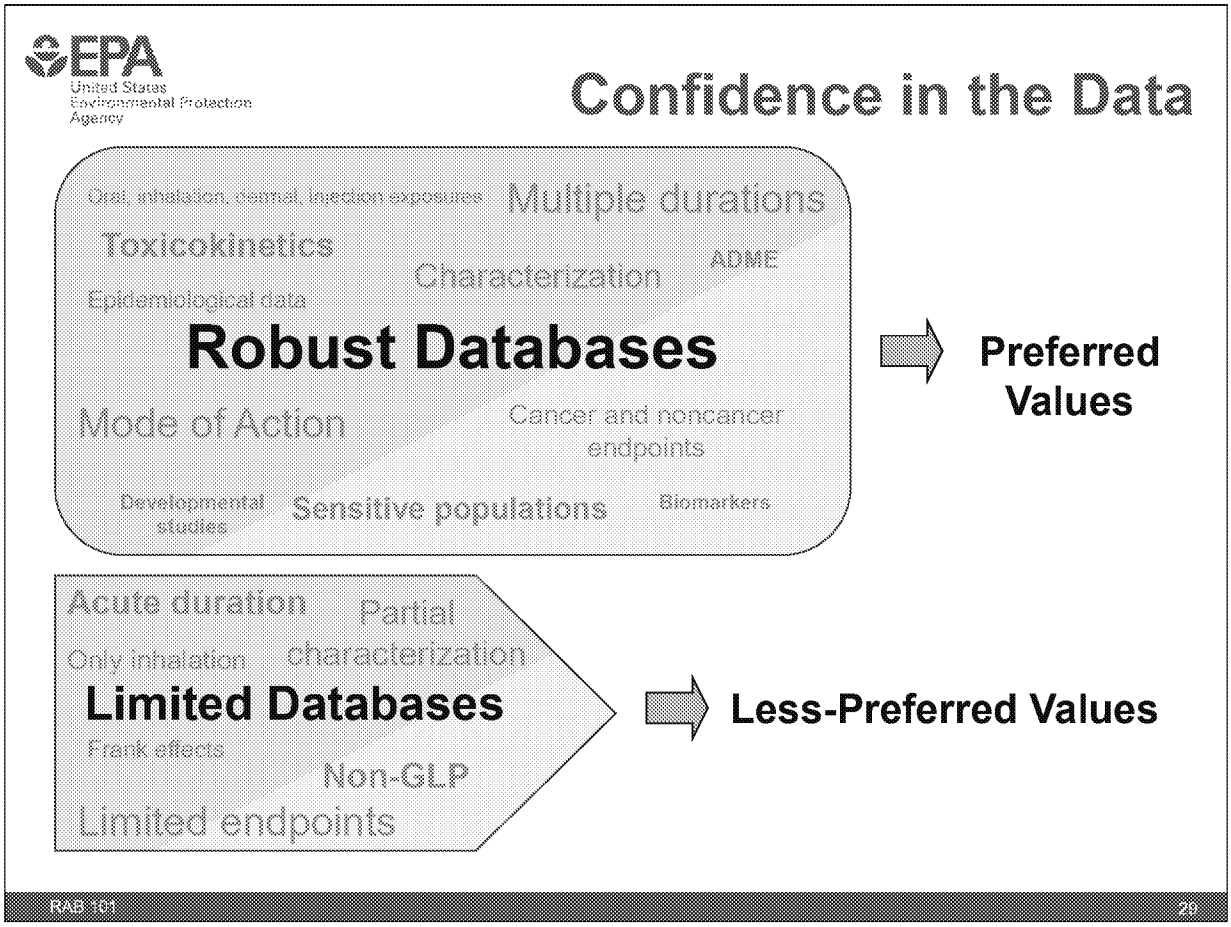
Ambient and General Public Values: Other Examples

Guideline	Organization and Context	
NAAQS National Ambient Air Quality Standards	EPA United States Environmental Protection Agency	Mandated by the CAA for criteria pollutants in air to protect the public from pollutants considered harmful to public health and the environment.
WQC Water Quality Criteria	EPA United States Environmental Protection Agency	Mandated by the CWA for over 150 pollutants in surface waters, EPA provides recommended concentrations that can be used by states and tribes to set legally enforceable water quality standards based on a specified use.
MRL Minimal Risk Level	ATSDR	Recommended limits to support the identification of contaminants potentially harmful to human health at hazardous waste sites.

Ambient and general public reference values not contained in IRIS but developed by EPA include the NAAQS standards and the water quality criteria.
Other entities, including the CDC Agency for Toxic Substances and Disease Registry develop reference values or methodologies for deriving these values.
More details on these and other ambient and general public reference values are provided in your reading packet.



Although the exposure specifications provide a context for exposure, a quantitative limit to exposure cannot be determined without understanding the potential human health or ecological effects that result.

All reference values are based – to various degrees – on toxicological data that provide some basis for a relationship between a dose or exposure concentration and a specific effect (i.e., a dose- or exposure-response relationship).

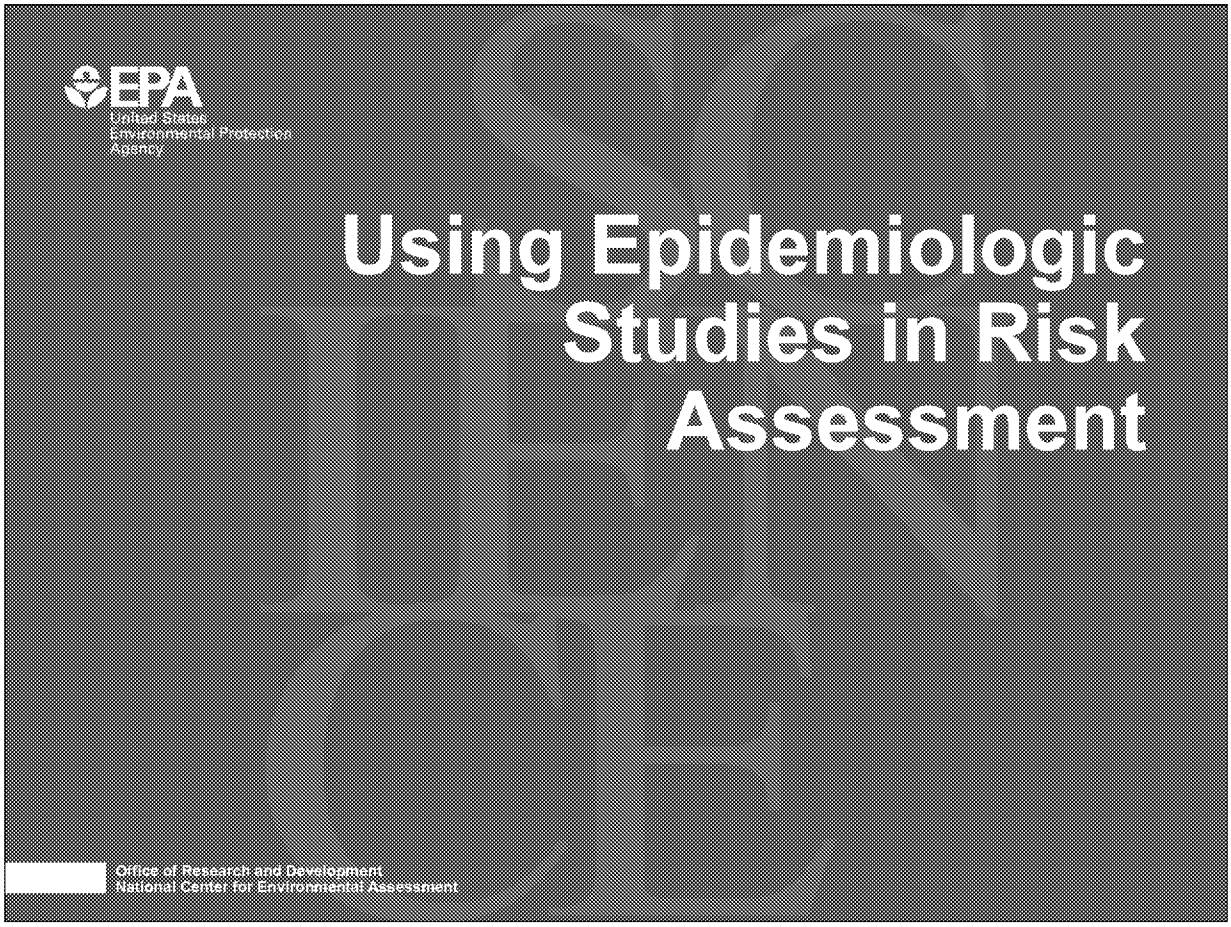
Generally speaking, the more robust the database of toxicological and supporting information, the more confidence there is in this relationship. A robust database will include data on the following:

different endpoints,
potential modes of action,
multiple routes of exposure,
different target populations, and
multiple durations of exposure.

Robust databases also include information about the chemical and physical attributes of the substance and other supporting data.

In many cases, certain type of studies – such as a reproductive study or chronic duration study – might be missing from the database, but other studies – such as developmental studies and acute studies – do provide data from which effects might be extrapolated, considering a degree of uncertainty. An incomplete database is not preferred when developing guidelines and standards, but often this is the reality of risk assessment.

Extrapolation and uncertainty are concepts that are covered in more depth in the next set of courses, the Basics of Human Health Risk Assessment.



The following are some examples of NCEA products used in risk assessment.

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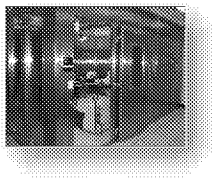
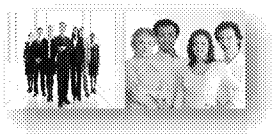
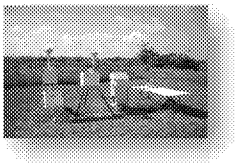
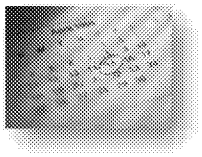
Evaluating Individual Studies: Chance, Bias, and Confounding









- Overall study design
  - What kind of study design was used?
  - What is the sample size?
- Exposure characterization
  - What are the comparison groups?
- Outcome
  - How were outcomes measured?
  - How likely were non-differential and differential misclassification?
  - Was follow-up sufficient?
- Analysis
  - Were relevant confounders assessed properly?
  - Did exposure precede disease?

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Evaluating Individual Studies: Inadequate Exposure-Response Data

- Many epidemiology studies provide little or no information about exposure-response relation
  - "Ever-never" exposures; limited range of exposures
  - Duration may be a weak proxy for total exposure if exposure changes (decreases) over time
- Absence of exposure-response analysis does not invalidate the study, and does not negate its usefulness in the hazard identification phase of risk assessment

Evaluating Exposure-Response Data from Individual Studies

- Effect of non-differential exposure misclassification on exposure-response curve
- Non-linear patterns of increasing exposure-response often seen

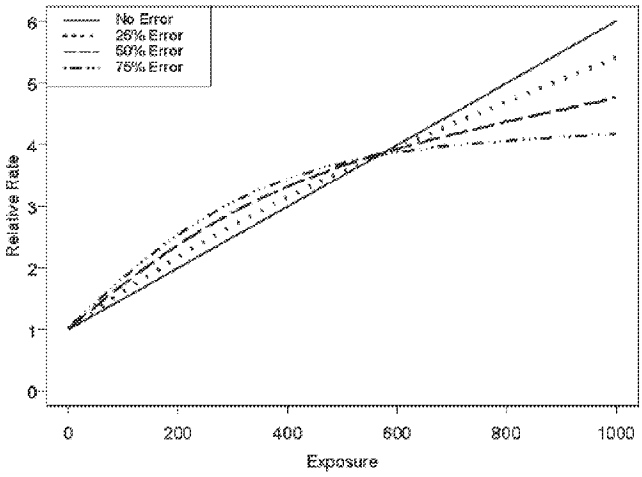

Figure 3. Results from a simulation study of the effect of random misclassification of exposures on a true linear exposure relationship.

Attenuation of exposure-response curves in occupational cohort studies at high exposure levels.
Stayner L. et al. *Scand J Work Environment Health*. 2003; 29: 317-324.

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Evaluating Individual Studies: Summary

- Rare for one single study to provide causal link
- More often:
  - Several relevant epidemiology studies available
  - Evaluate collection of studies from the perspective of hazard identification:
    - Does exposure cause disease?

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Evaluating a Collection of Studies

- **Weight of Evidence Approach**
  - How does the collection of studies address chance, bias, and confounding as explanations for the observed association between an exposure and a disease?
  - Weight can be given to studies with **greater validity and/or precision**, but this may not be straightforward.
    - Precision and validity may be inversely related

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Weight of Evidence: Examining Possible Explanations

- Similar to approach for individual studies, with a few more tools to use
  - Chance (precision)
    - Meta-analysis could improve precision
  - Bias
    - Examine effect of study attributes
      - For example, consider type of exposure assessment. Are stronger effects seen with methods that have less non-differential misclassification?
  - Confounding
    - Could be evaluated and controlled for differently across studies

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Integrated Science Assessments (ISAs)

Weight-of-Evidence for Causal Determination

Source: Preamble to Integrated Science Assessments (https://www.epa.gov/isa)

Table II Weight of evidence for causal determination.

	Health Effects	Ecological and Welfare Effects
Causal relationship	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures (e.g., doses or exposures generally within one to two orders of magnitude of recent concentrations). That is, the pollutant has been shown to result in health effects in studies in which chance, confounding, and other biases could be ruled out with reasonable confidence. For example: (1) controlled human exposure studies that demonstrate consistent effects; or (2) observational studies that cannot be explained by plausible alternatives or that are supported by other lines of evidence (e.g., animal studies or mode of action information). Generally, determination is based on multiple high-quality studies conducted by multiple research groups.	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures (e.g., doses or exposures generally within one to two orders of magnitude of current levels). That is, the pollutant has been shown to result in effects in studies in which chance, confounding, and other biases could be ruled out with reasonable confidence. Controlled exposure studies (laboratory, or small- to medium-scale field
	Evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposures. That is, the pollutant has been shown to result in health effects in studies where results are not explained by chance, confounding, and other biases, but uncertainties remain in the evidence overall. For example, (1) observational studies show an association, but confounding or other biases cannot be ruled out, and/or other lines of evidence (e.g., human exposure, animal, or mode of action information) are limited or inconsistent; or (2) toxicological evidence from multiple studies in different laboratories demonstrate effects, but no human data are available. Generally, determination is based on multiple high-quality studies.	
Suggestive, but not sufficient, to infer a causal relationship	Evidence is suggestive of a causal relationship with relevant pollutant exposures but is limited, and chance, confounding and other biases cannot be ruled out. For example, (1) when the body of evidence is relatively small, at least one high-quality epidemiologic study shows an association with a given health outcome and/or at least one high-quality toxicological study shows effects relevant to humans in animal species; or (2) when the body of evidence is relatively large, evidence from studies of varying quality is generally supportive but not entirely consistent, and there may be coherence across lines of evidence (e.g., animal studies or mode of action information) to support the determination.	Evidence is suggestive of a causal relationship with relevant pollutant exposures. but chance, confounding, and other biases cannot be ruled out. For example, at least one high-quality study shows an effect, but the results of other studies are inconsistent.
Inadequate to infer a causal relationship	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quantity, quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.	The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.
Not likely to be a causal relationship	Evidence indicates there is no causal relationship with relevant pollutant exposures. Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering at-risk populations and lifestages, are mutually consistent in not showing an effect at any level of exposure.	Several adequate studies, examining relationships with relevant exposures, are consistent in failing to show an effect at any level of exposure.

… doses or exposures generally w/in 1-2 orders of magnitude of recent concentrations

. . . chance, confounding, and other biases could be ruled out with reasonable confidence

. . . multiple high-quality studies by multiple research groups

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This is a table directly from the ISA that highlights the rationale for making causal determinations for each level of the hierarchy. The delineation between each level is based on our ability to rule out with reasonable confidence chance, confounding and other biases. Additionally we take into consideration doses and exposure concentrations along with the overall quality of the studies evaluated. It is important to note that in evaluating the overall weight of evidence we are also assessing consistency of effects within a discipline, the coherence of effects across disciplines, and biological plausibility.

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What About Quantitative Synthesis Procedures?

Types of procedures

- Meta-analysis
- Pooled analysis
- Meta-regression

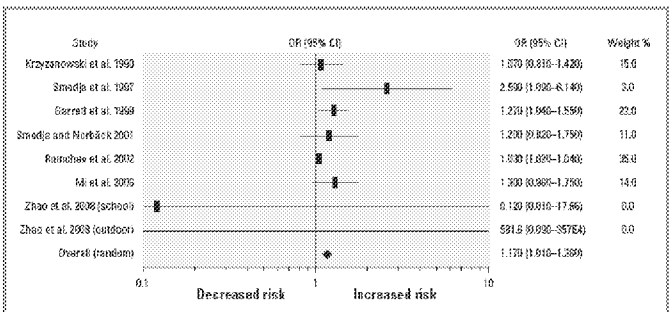

Figure 2. Forest plot of the relative risk estimates and their 95% CIs from the studies included in the meta-analysis of the association between formaldehyde exposure and asthma in children based on a random-effects model.

Source: McGwin et al. (2010) Environ Health Perspect 118:313-317.

Advantages

- Can gain precision
- Can evaluate effects of different aspects of study design

Disadvantages

- Feasibility
- Exclusions (based on type, access to data) may affect results
- Marginal cost may be high, marginal gain may be low

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Assessing Causality: Bradford Hill Guidelines

- **Considerations for epidemiology data**
  - Temporal relationship (exposure precedes disease)
  - Consistency across studies
  - Strength of association (considering units of exposure)
  - Exposure-response relationship
- **Considerations drawing in other data**
  - Plausibility and coherence
- **Considerations of low utility**
  - Specificity (single cause, single effect)

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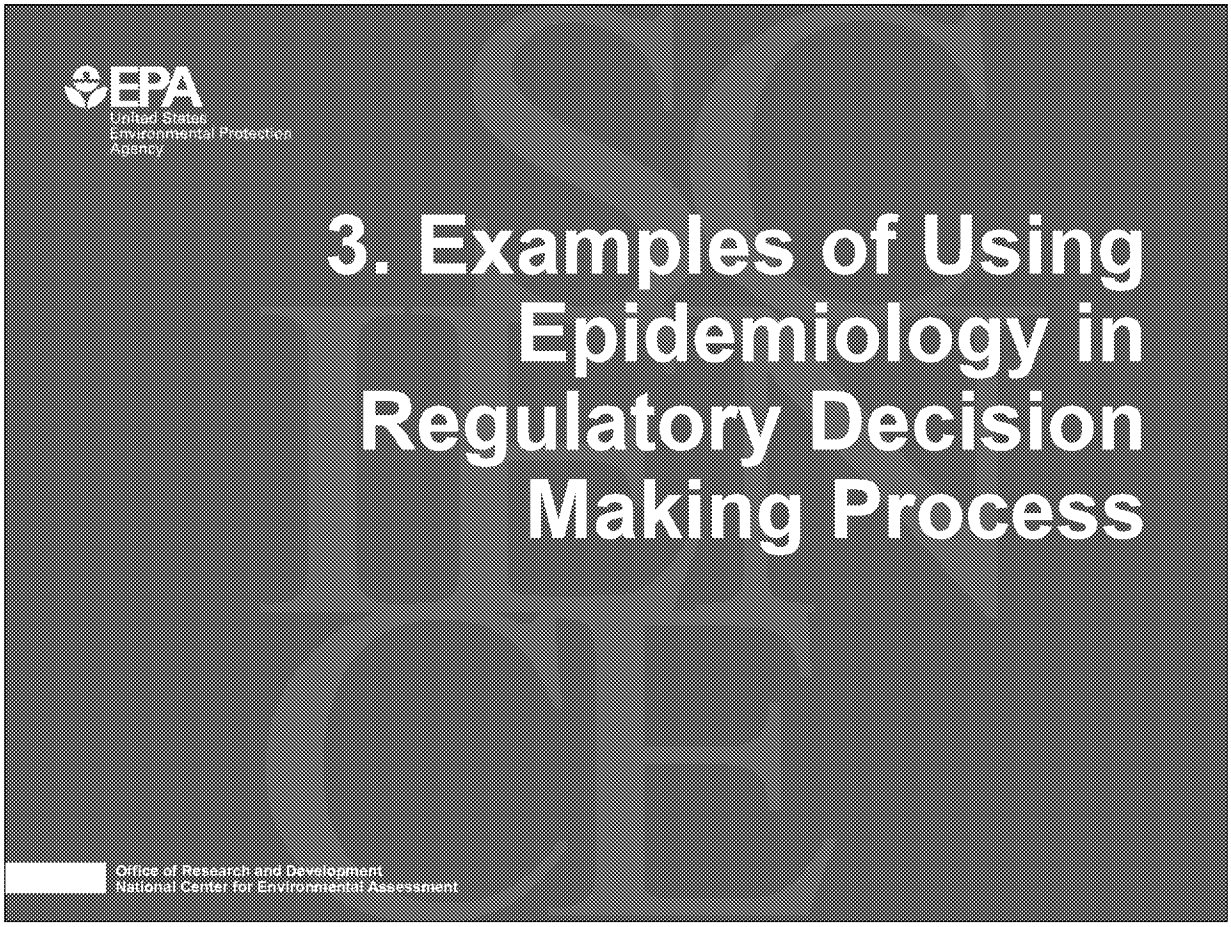
Using Epidemiologic Data in Exposure-Response Assessment

- **Numerous examples:**
  - Cardiovascular disease (carbon monoxide)
  - Lung function (ozone, ammonia)
  - Neurological effects (toluene, manganese)
  - Lung cancer (asbestos, chromium)
  - Leukemia (benzene, 1,3-butadiene)
- **Primary considerations for choosing data to model:**
  - Chance, bias, and confounding ruled out or minimized
  - Quality of exposure measurements



The following are some examples of NCEA products used in risk assessment.

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Overview

- Together, epidemiologic, controlled human exposure, animal toxicological and mechanistic studies provide valuable evidence to inform policy makers as they make science-based regulatory decisions
- Observational epidemiologic studies are unique
  - Can include susceptible or vulnerable individuals who might be at greatest risk
  - Provide information about health effects occurring at real-world (ambient) concentrations
  - Can include various relevant health outcomes (e.g., mortality, emergency department visits) not often evaluated in animal toxicological or controlled human exposure studies

The evaluation of health evidence that can be used to inform regulatory policy can come from epidemiologic, animal toxicological and controlled human exposure studies. In an ideal scenario, you would have substantial evidence bases from all three scientific disciplines. Experimental studies (these are the animal toxicological studies and the controlled human exposure studies) are useful in distinguishing the independent effect of a chemical or pollutant from an effect that could be due to a co-occurring pollutant or chemical or other potential confounding factors.

On the other hand, observational epidemiologic studies provide information on effects occurring at real-world or ambient concentrations, and may include a range of individuals with different ages and health status who might be at greatest risk. Epidemiologic studies are also able to evaluate certain health outcomes, ED visits for example, that can't be measured in experimental studies.

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Evidence from Epidemiologic Studies

Results from epidemiologic studies can be used in two ways to support regulatory decision making:

1. **Qualitatively,** to inform the hazard identification aspect of risk assessment; and

2. **Quantitatively,** to inform hazard identification, the dose-response relationship and/or the health impact (burden) component of risk assessment

The results from epidemiologic studies can be used in a couple of different ways to inform regulatory policies.

First, epidemiologic evidence can be used qualitatively to inform hazard identification. For example, systematic reviews of epidemiologic evidence can help to characterize the body of evidence used to inform policy, including consistency and coherence of the results.

In addition, epidemiologic evidence can be used quantitatively to estimate the magnitude or strength of the association, characterize the shape of the concentration-response or dose-response relationship, or used to estimate the health impact or burden of a change in pollutant or chemical exposure

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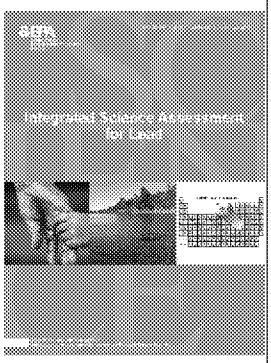
Example #1: Review of Pb NAAQS

•Synthesis of policy-relevant science to provide scientific support for periodic review of national ambient air quality standards (NAAQS)

•**Qualitative** assessment of the evidence
- •Assess the body of relevant literature, building upon evidence available during previous NAAQS reviews, to draw conclusions on the strength of the relationships between relevant pollutant exposures and health outcomes

•Information regarding **quantitative** relationships, including:
- •concentration-, exposure- or dose-response relationships
- •exposure conditions (exposure, duration and pattern) that are important

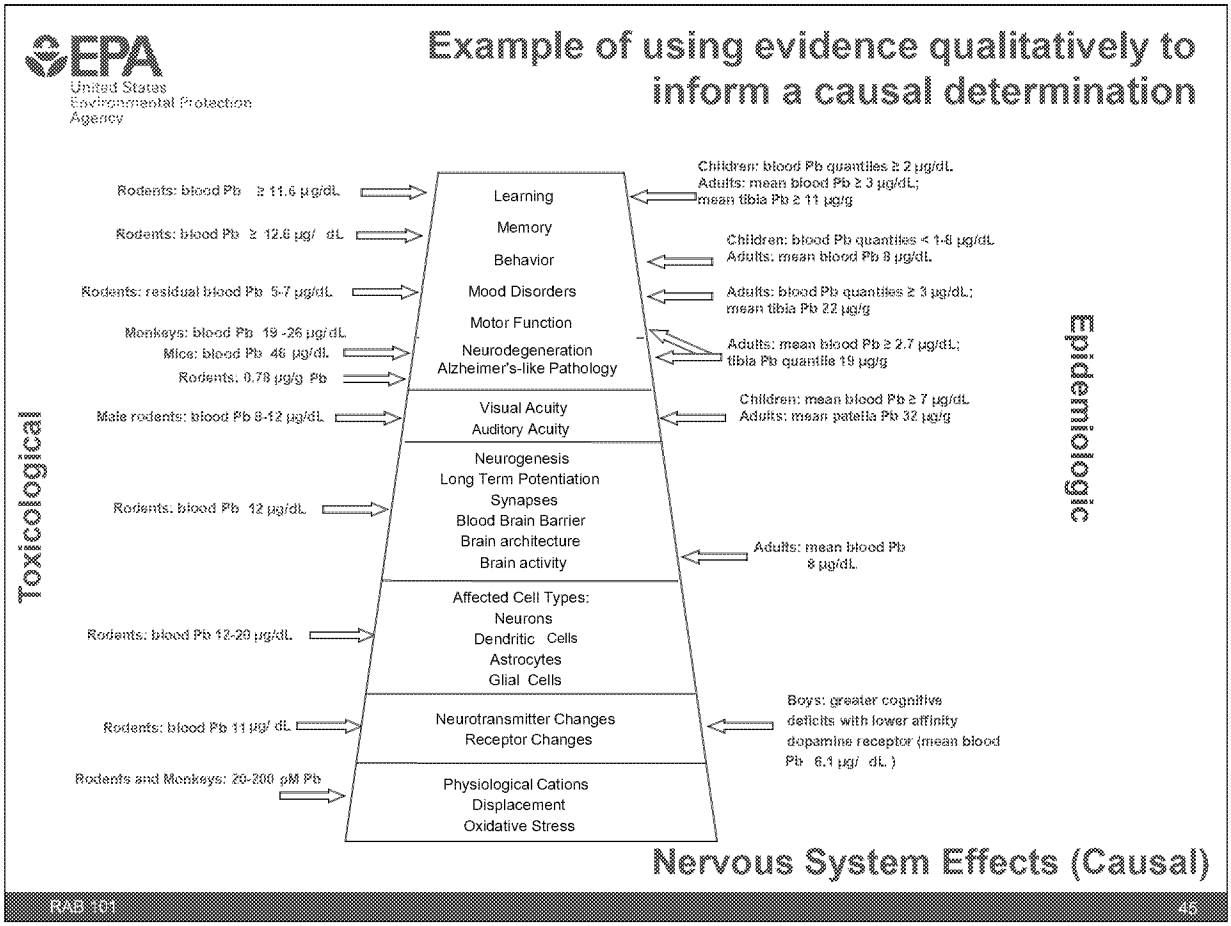


RAB 101 44

My first example is for the review of the national ambient air quality standard (or NAAQS) for lead (Pb). The review of the air quality criteria for lead is mandated under the clean air act, and the synthesis of the scientific evidence that serves as the scientific base for the NAAQS review is compiled in the Integrated Science Assessment (or ISA)

In the ISA, epidemiologic evidence is assessed qualitatively to draw conclusions on the causal relationships between exposure to Pb and health outcomes. The ISA concluded causal relationships between Pb exposure and several cardiovascular endpoints, reproductive outcomes, and perhaps most well-know, cognitive function decrements (often measured as decreases in IQ).

In addition, the epidemiologic evidence can be used quantitatively to inform exposure-response relationships



First, I wanted to show this figure that demonstrates how epidemiologic and toxicological evidence are integrated qualitatively to reach a causal determination. This is an example for how Pb causes nervous system effects. I'll note that this figure was not included in the Pb ISA, but developed internally to help us synthesize and integrate the evidence. The pyramid in the middle includes different neurological endpoints, with the least severe along the bottom and the most severe at the top. The idea is to show where there is evidence for the progression of these different neurological endpoints due to Pb exposure. The evidence from animal toxicological studies is in green on the left side of the pyramid and the epidemiologic evidence is in purple on the right side of the pyramid.

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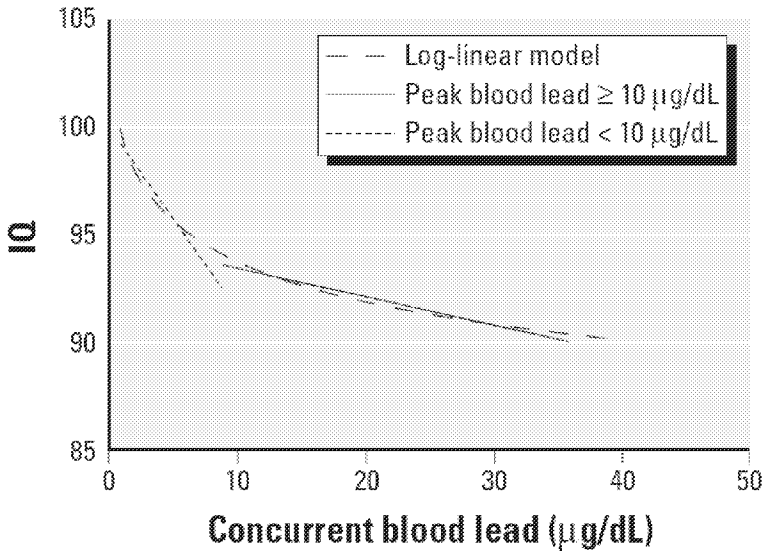
Examples of using evidence quantitatively to inform a causal determination



Nonlinear association between blood Pb level and cognitive function in children

Source: Lanphear et al. (2005)

RAB 101 46

Here we can see how the results of epidemiologic studies can be used quantitatively, in this case to characterize the non-linear concentration-response function for blood lead level and cognitive function in children. We can see that the steepest declines in IQ occur at the lowest blood Pb concentrations (<10 ug/dl) and that the slope is less steep when blood lead levels are >10 ug/dl.

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Examples of using evidence quantitatively to inform a causal determination

Table 3-3. Summary of quantitative relationships of IQ and blood Pb for analyses with blood Pb levels closest to those of young children in the U.S. today.

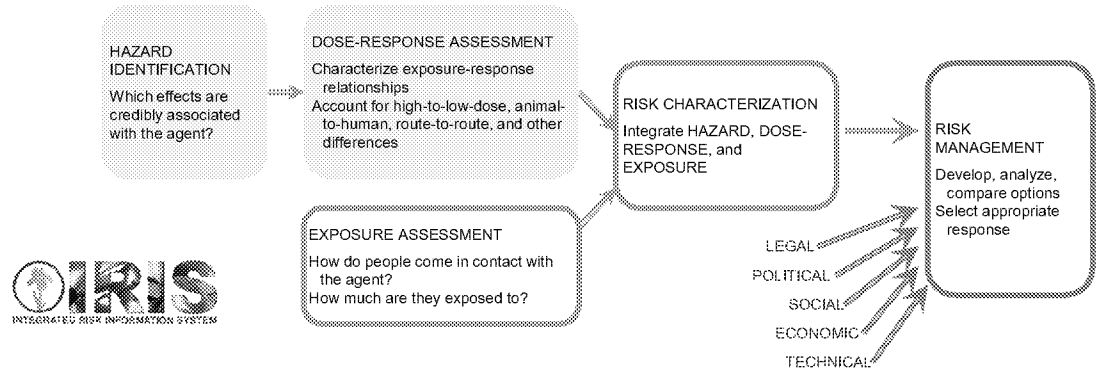
Blood Pb Levels (µg/dL)			Average Linear Slope[A] (IQ[B] points per µg/dL)
Geometric Mean	Range (min-max)	Study/Analysis	
2.9	0.8 – 4.9	Tellez-Rojo et al (2006)[B], subgroup with concurrent blood Pb <5 µg/dL	-1.71
3.3	0.9 – 7.4	Lanphear et al (2005)[C], subgroup with peak blood Pb <7.5 µg/dL	-2.53
3.32	0.5 – 8.4	Canfield et al (2003)[C], subgroup with peak blood Pb <10 µg/dL	-1.79
3.8	1 - 9.3	Bellinger and Needleman (2003)[C], subgroup with peak blood Pb <10 µg/dL	-1.56
		Median value	-1.75

Source: U.S. EPA 2013 Pb ISA

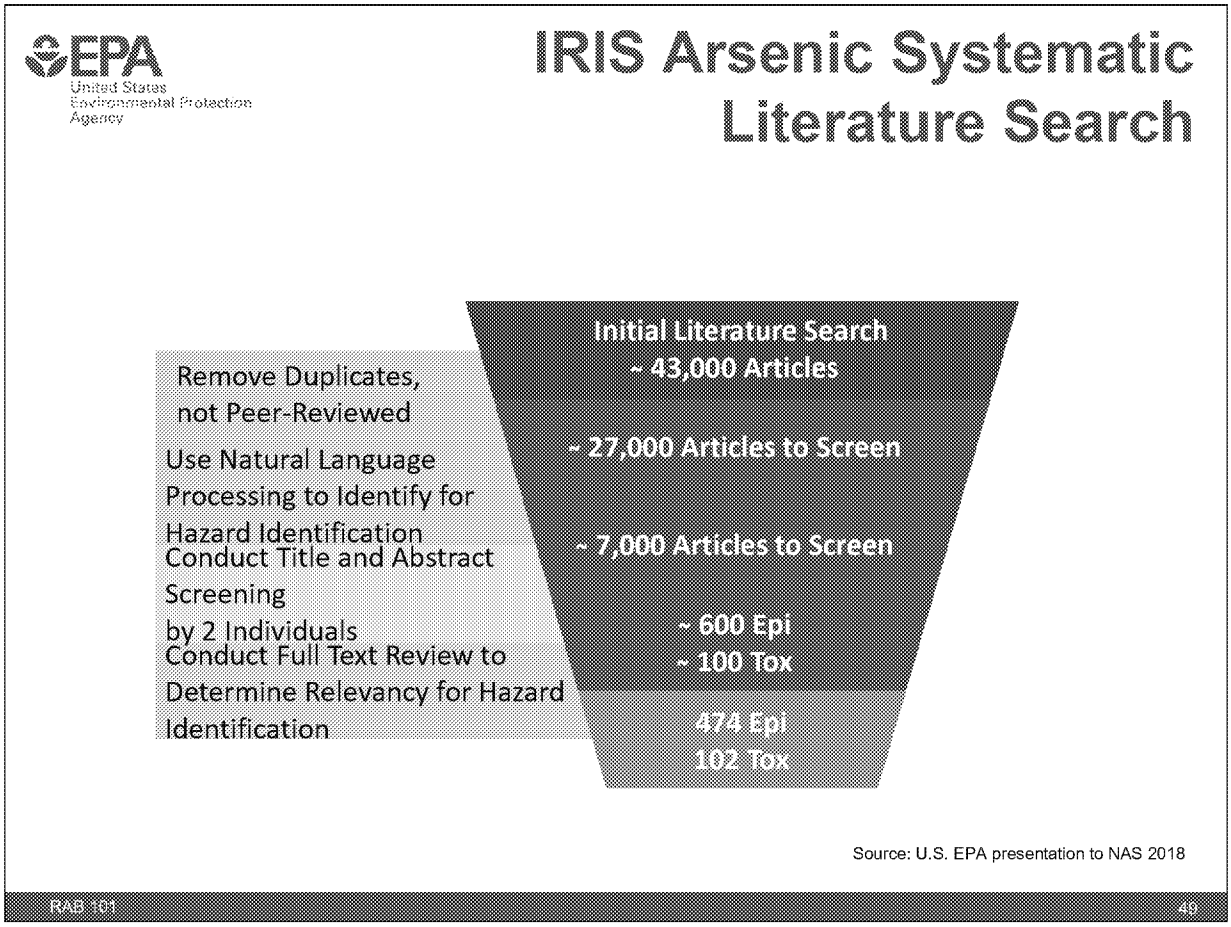
Here is another example of how the results of multiple epidemiologic studies can be used quantitatively. This Table is from the 2013 Pb ISA and demonstrates the consistency in the decline in IQ points per ug/dl increase in blood Pb level.

Example #2: IRIS Assessment of Arsenic

- Provides **qualitative** and **quantitative** health information on chronic exposures to specific chemicals
- IRIS database contains toxicological assessments of over 500 chemicals found in the environment



The Integrated Risk Information System, or IRIS, is a human health assessment program that evaluates hazards that may result from lifetime exposure to environmental contaminants. IRIS toxicological assessments use health evidence both quantitatively and qualitatively to evaluate chronic exposures to more than 500 different chemicals found in the environment. You may have noticed that I said "toxicological" assessments. Often, the bulk of health evidence for IRIS chemicals comes from toxicological studies, though evidence from epidemiologic studies is integrated into IRIS assessments when available. I chose to use the IRIS assessment of arsenic as an example because it is a bit of an anomaly in that it is one of the few IRIS chemicals for which there is a substantial body of epidemiologic evidence.



Just to demonstrate this point, you can see that an initial literature screen identified about 43,000 peer-reviewed articles, which included nearly 500 epidemiologic studies relevant to the IRIS arsenic assessment. And note that there were about 100 toxicological studies that were identified for the assessment.

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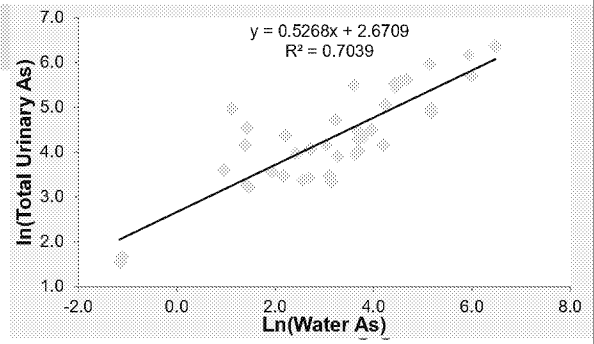
Examples of using epidemiologic evidence quantitatively

- Results from epidemiological studies are expressed in terms of different exposure/dose metrics
- Integrate results from a number of studies that explore exposure/intake-biomarker relationships due to availability of PBPK model
- Compare and quantitatively assess uncertainty and variability in relationships between exposure and excretion

Exposure/Dose Metric	Number of Candidate Data Sets
Water arsenic concentration	6
Daily arsenic intake from water	5
Cumulative exposure from water	18
Cumulative intake from water	6
Dietary intake	2
Urinary excretion	5
Toenail arsenic	1
Multiple metrics	14



Source: U.S. EPA presentation to NAS 2018

The point that I want to emphasize for this is example is how the epidemiologic evidence can be used quantitatively. One of the qualities of the epidemiologic evidence base is that a number of different exposure or dose metrics are used. In the Table on the left you can see the different metrics used in some of the epidemiologic studies. Often, we can compare the results across epidemiologic studies with different exposure metrics qualitatively, but not quantitatively. However, in this case, we are fortunate to have a physiologically-based pharmaco-kinetic (PBPK) model available that allows for the combination of results from different studies. The Figure on the right shows the results of these reconciled studies and how they can be used quantitatively to inform the concentration (arsenic in drinking water on the x axis)-exposure (arsenic in urine on the y axis) relationship. Once these studies have been reconciled in this manner, they can be combined in a meta-analyses and quantitatively inform additional analyses that may support the assessment.

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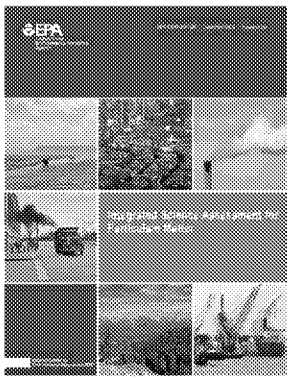
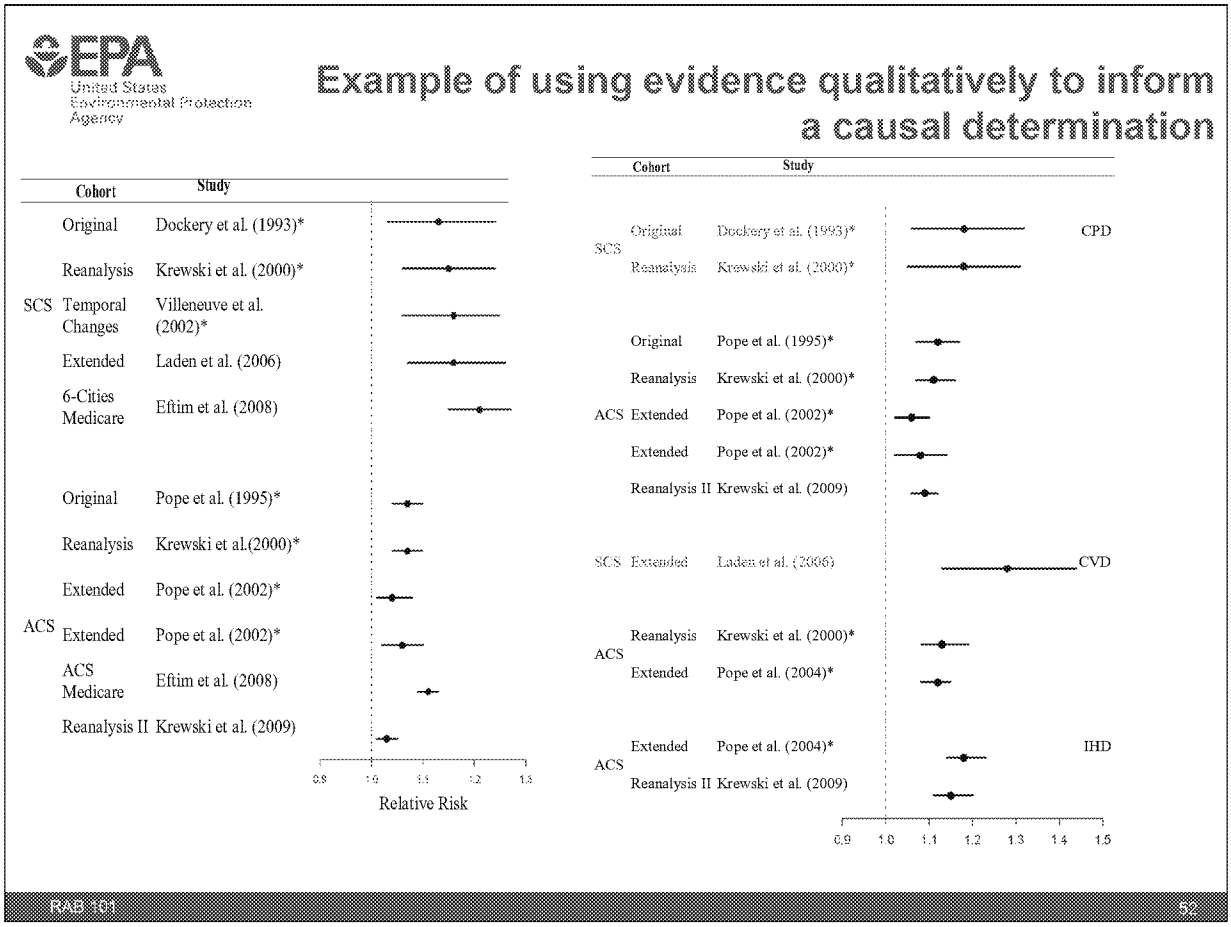
Example #3: Review of PM NAAQS

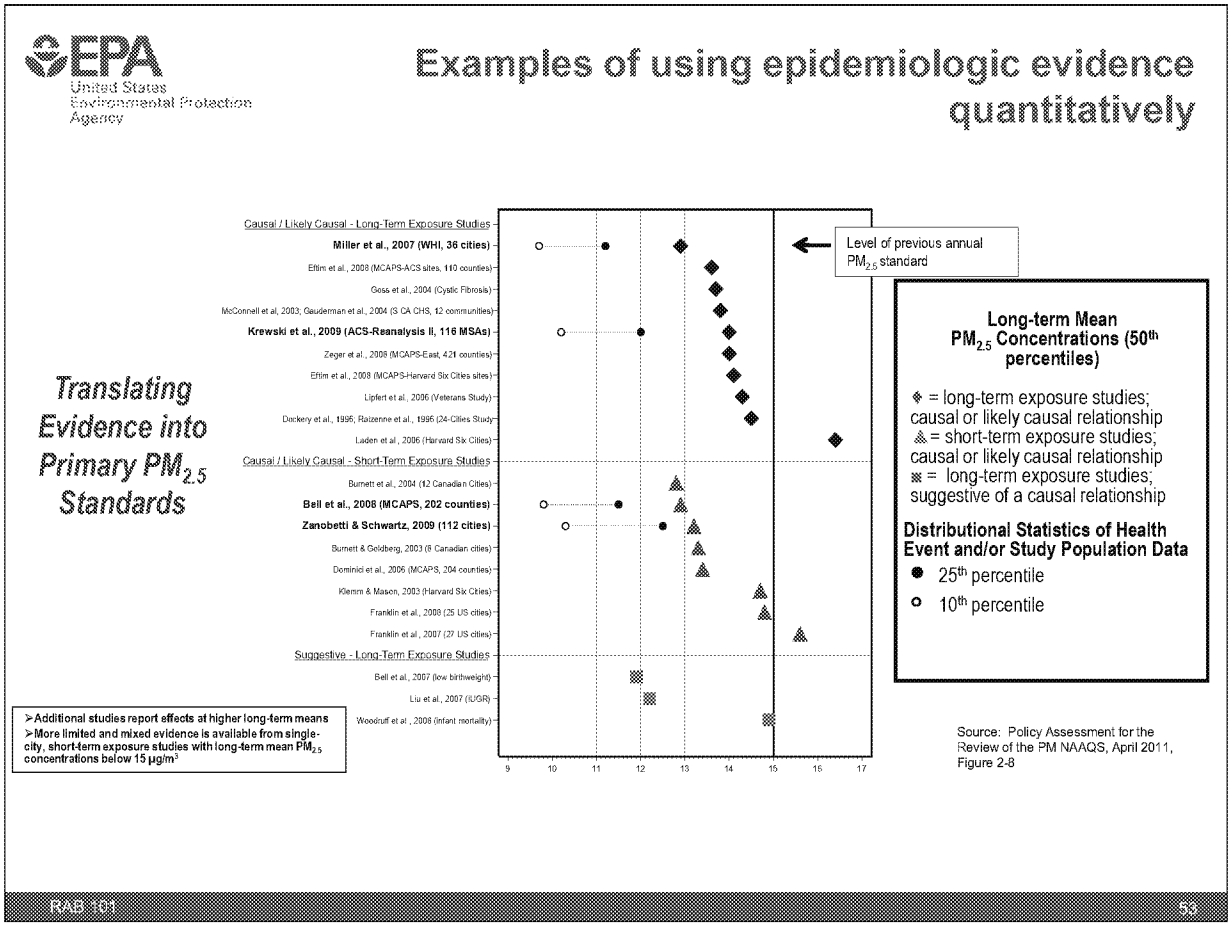
- Synthesis of policy-relevant science to provide scientific support for periodic review of national ambient air quality standards (NAAQS)
- **Qualitative** assessment of the evidence
- Information regarding **quantitative** relationships, including concentration-response relationships



Recall from our discussion of Pb that the integrated science assessment (ISA) is the scientific basis for the NAAQS review of air pollutants, and includes both qualitative and quantitative assessments of the epidemiologic data. The epidemiologic evidence is integrated with evidence from animal toxicological studies and controlled human exposure studies and used qualitatively to make causal determinations



These two figures summarize the results of two of the seminal studies that were included in the 2009 PM ISA – the Harvard Six Cities Study (abbreviated as SCS) and the American Cancer Society cohort (abbreviated as ACS). The figure on the left is represents the results of the original analyses, as well as several re-analyses and extended analyses of these two cohorts for long-term PM2.5 exposure and total (non-accidental) mortality. Similarly, the figure on the left shows the results for cardiopulmonary (CPD) mortality, cardiovascular mortality (CVD) and ischemic heart disease mortality (IHD). The consistent, positive associations observed across these studies provided the strongest evidence leading to the causal determination concluded in the 2009 PM ISA.



This figure demonstrates how epidemiologic studies were used quantitatively to help determine the level of the PM2.5 standard in the 2012 NAAQS review

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4. Using Epidemiology in Benefits Analysis

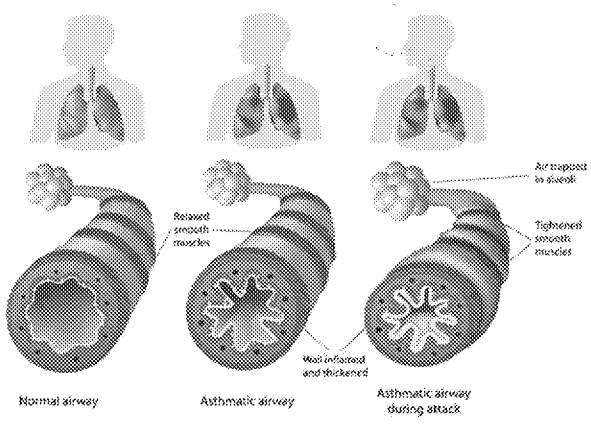
BenMAP
COMMUNITY EDITION

Office of Research and Development
National Center for Environmental Assessment

EPA United States Environmental Protection Agency

Objectives

1. **What is a benefits analysis?**
   - What kinds of questions does it help answer?
   - How does it fit within a policy analysis?
2. **What are the steps in calculating air pollution-related health impacts?**
   - What are the air pollution-related effects?
   - What data sources are needed to estimate benefits?
3. **What tools are available?**
   - BenMAP – CE
   - Global Burden of Disease (GBD) Module



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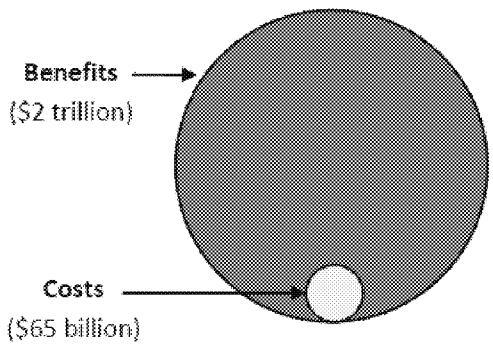
Why Estimate the Benefits of an Air Quality Policy?

- Answers the basic question:
  - What are the health and economic benefits of emissions controls and the associated improvements in air quality?
- To compare benefits against the costs of a policy
- Can help decide between different policies
- Can improve efficiency and effectiveness
- Can help determine if a particular policy is "worth it" to society

Benefits and Costs of the U.S. Clean Air Act



Source: Section 812 Analysis of the Benefits and Costs of the Clean Air Act

Section 812 Analysis of the Benefits and Costs of the Clean Air Act
Costs are incurred by industries that are targeted for reductions in emissions of the NAAQS pollutants.
The actual setting of the standard does not allow for the consideration of costs. Costs are only considered in developing control strategies during the implementation process.

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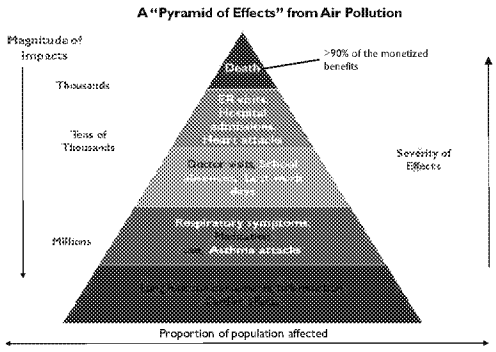
Determining Which Health Effects to Evaluate in Cost-Benefit Analyses

- Multi-step process
- Requires Addressing a Series of Questions:
  - What is our overall level of confidence that exposure to an air pollutant can cause the health effect being evaluated?
  - Are there epidemiologic studies that examine the relationship between the air pollutant and health effect?
  - What location or locations does the epidemiologic study encompass?
  - Is there corresponding incidence data available at the same spatial scale as the epidemiology study for the health effect of interest (e.g., nationally, city-specific, etc.)?



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How does EPA estimate the health and economic impacts associated with changes in air quality?

- U.S. EPA's Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP – CE)
  - Free and open source program that allows users to use data supplied by EPA or their own data to estimate the health and economic benefits of various air quality scenarios
  - Available at: https://www.epa.gov/benmap

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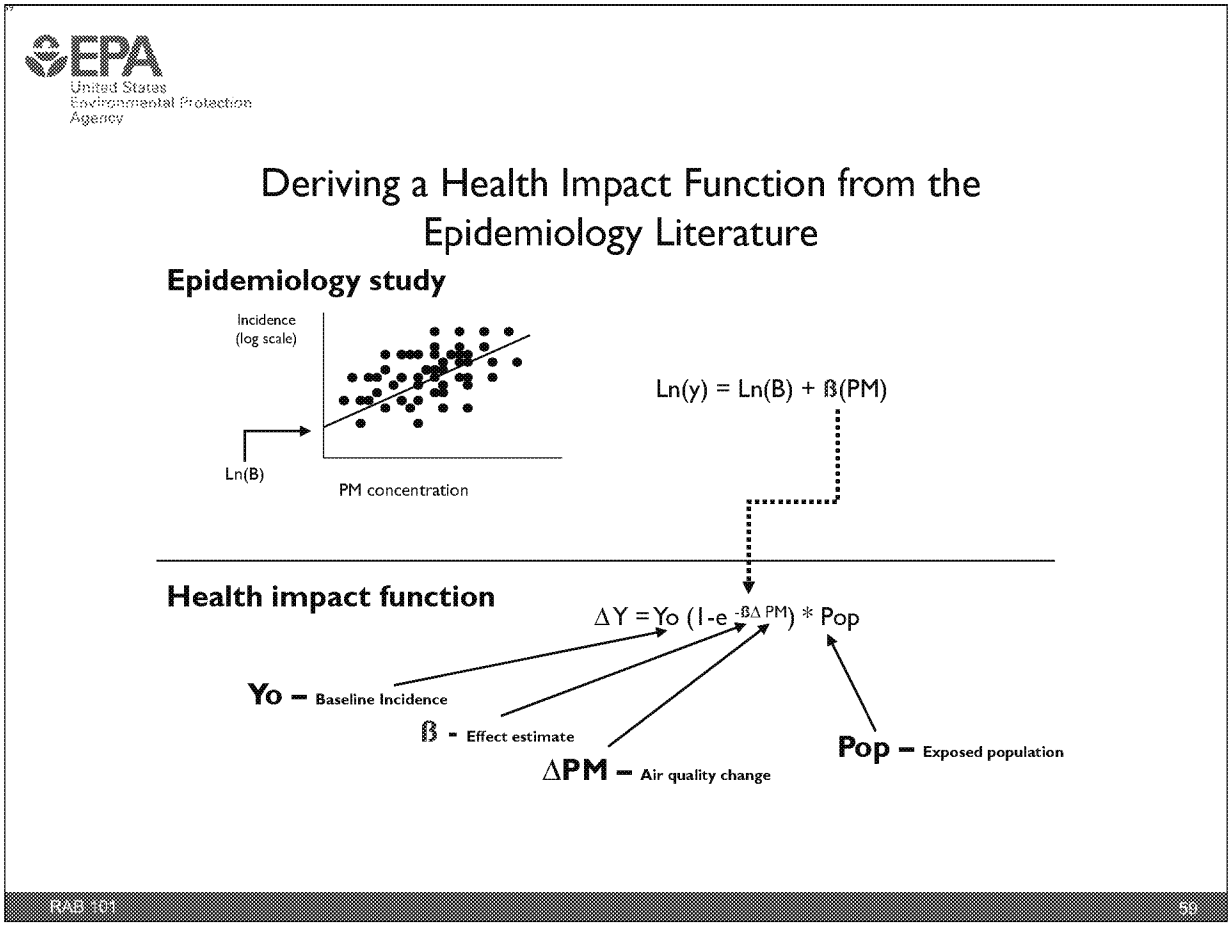

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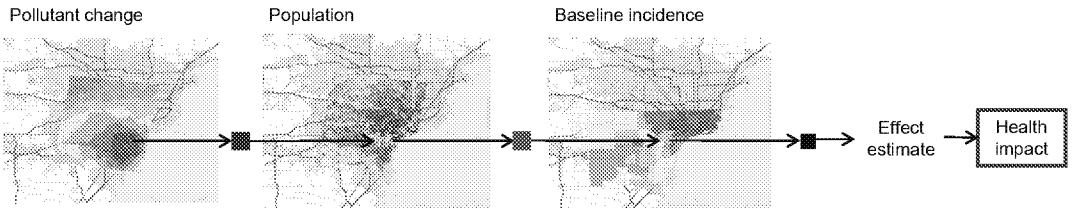
Very simplistic example of the relationship between air pollution and some health outcome that is depicted in an epidemiologic study.

Rather simple algebraic equation is used to estimate the impact of some change in AQ.

Steps to Calculating Health Impacts

$\Delta Y = Yo\ (1-e^{-\beta \Delta PM}) * Pop$



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In the previous slide we defined the general health impact function, but how do you then take that and calculate the health impacts? The first step is identifying some spatial domain over which you want to estimate the health impacts.

Using either modeled or monitored air quality data you would identify the pollutant change of interest.
For that same spatial domain, obtain population data as well as baseline incidence data for the health effect being examined.
Lastly, the effect estimate from the epidemiology study is used to calculate the health impact.

To ensure the proper calculation of the health impact the population and baseline incidence data needs to match the characteristics of the study that the effect estimate is derived from. For example, if the epidemiology study only consists of people over the age of 25 and focuses on mortality then the population and baseline incidence data should match.

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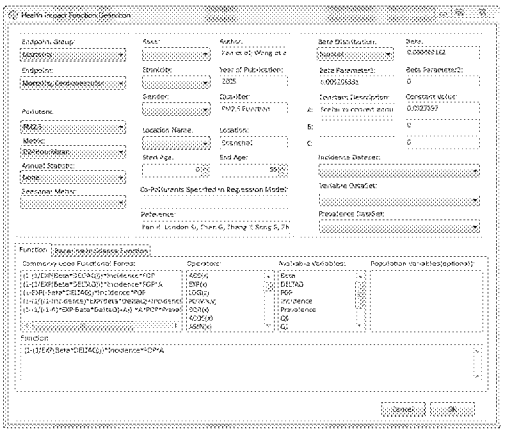
Health Impact Functions

$$\Delta Y = Y_o (1 - e^{-\beta \Delta PM}) * Pop$$

- BenMAP-CE contains over a 100 health impact functions for the U.S. and China
- Users can download EPA's default functions for $PM_{2.5}$
  - EPA's previous functions for NO_2, SO_2, and lead are also available
- Users can add and edit their own health impact functions using the function editor



BenMAP-CE's Health Impact Function Editor

Avg time (8 hr max, 1 hour max, 2 hour max). Ensuring we have the proper pop and incidence data.

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Example Benefits: 2011 Policy Reducing Emissions from Power Plants in U.S.

Summary of health impacts avoided

Health endpoint	Value
$PM_{2.5}$-related mortality (Pope et al. 2002)	14,000 (4,000—25,000)
$PM_{2.5}$-related mortality (Laden et al. 2006)	36,000 (17,000—56,000)
O_3-related mortality (Bell et al. 2004)	50 (17—84)
O_3-related mortality (Levy et al. 2005)	230 (160—300)
$PM_{2.5}$-related chronic bronchitis	9,200 (320—18,000)
$PM_{2.5}$-related non-fatal heart attacks	22,000 (5,800—39,000)
$PM_{2.5}$ and O_3-related respiratory hospitalizations	4,200 (1,500—6,700)
$PM_{2.5}$ and O_3-related emergency department visits	14,000 (7,200—21,000)

Monetized health and welfare benefits[A]

Endpoint	Value (billions of 2006$)
Human health[B]	
Pope et al. 2002 $PM_{2.5}$ and Bell et al. 2004 O_3 mortality estimates	$120 ($10—$360)
Laden et al. 2006 $PM_{2.5}$ and Levy et al. 2005 O_3 mortality estimates	$290 ($26—$840)
Visibility	$3.6
Total	
Pope et al. 2002 $PM_{2.5}$ and Bell et al. 2004 O_3 mortality estimates	**$120 ($10—$360)**
Laden et al. 2006 $PM_{2.5}$ and Levy et al. 2005 O_3 mortality estimates	**$290 ($26—$850)**

[A] All values rounded to two significant figures
[B] Discounted at 3%

RAB 101 62

Improvements in air quality can result in substantial reductions in a variety of health outcomes. Neal will detail the economic valuation aspect of benefits analysis, but as you can see the associated economic benefits for this particular rule are in the billions of dollars.

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Conclusions

Improving the Linkages between Air Pollution Epidemiology and Quantitative Risk Assessment

Neal Fann,[1] Michelle L. Bell,[2] Katy Walker,[3] and Bryan Hubbell[1]* Environmental Health Perspectives • VOLUME 119 | NUMBER 12 | December 2011

- Important considerations to ensure epidemiologic results are useful to risk assessors (and epidemiologists conducting meta-analyses)

Population
- Key population characteristics (e.g., age, race, sex, ethnicity, SES)
- Spatial distribution of population

Exposure Data
- Easily aggregated or transformed to allow comparison with other studies
- Forms or averaging times consistent with regulatory standard

Health Data
- ICD9/ICD 10 codes
- Are health effects age-adjusted?
- Are baseline mortality rates aggregated?

Effect Estimates
- Statistical model used
- Sensitivity analyses/Stratified models
- Potential confounders/effect measure modifiers considered
- Numerical data corresponding to figures included

In concluding, I want to mention a few factors to consider when either designing an epidemiologic study or evaluating the utility of an epidemiologic study for a risk assessment. And I'm going to refer to a paper published in 2011 by Neal Fann and colleagues that listed a number of important consideration to ensure that epidemiologic results are useful in risk assessment. This is not the full list from the paper, I have culled a few to highlight that relate to (1) Population, (2) Exposure Data, (3) Health Data, and (4) Effect Estimates.

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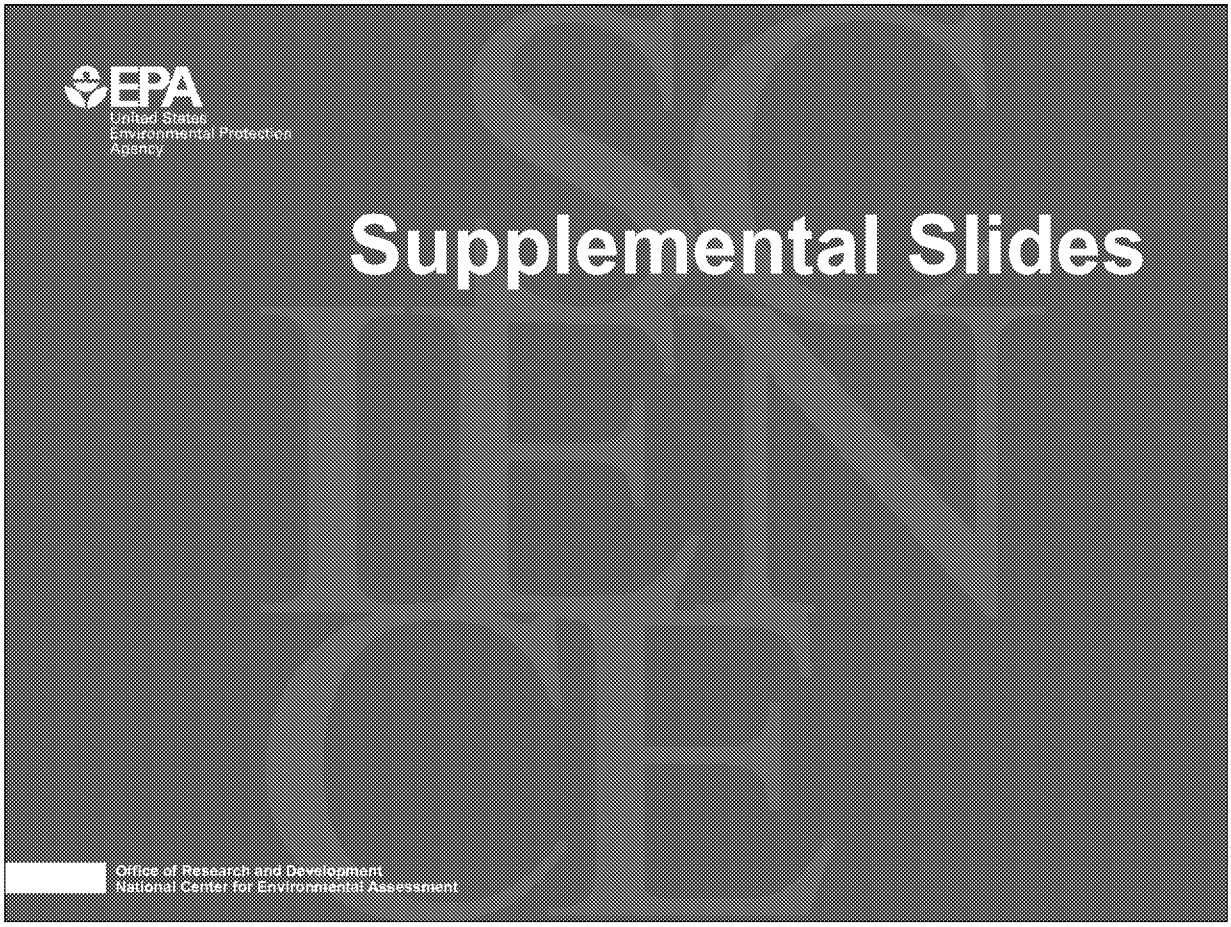
Wrap Up

- Epidemiologic studies provide important information for hazard identification and exposure-response assessment
- Associations in epidemiologic studies given greater weight when chance, bias, and confounding are minimized
  - Assess in individual studies
  - Assess in a collection of studies
- Exposure assessment approaches in some epidemiology studies enable their use in derivation of toxicity values

EPA has been a leader in the environmental risk assessment field since it was established in 1970.
A basic paradigm (with associated terminology and concepts) guides the application of risk assessment principles, but Terms can vary by context.
Processes continue to evolve,
ORD products and guidance are crucial for EPA risk assessments.



The following are some examples of NCEA products used in risk assessment.

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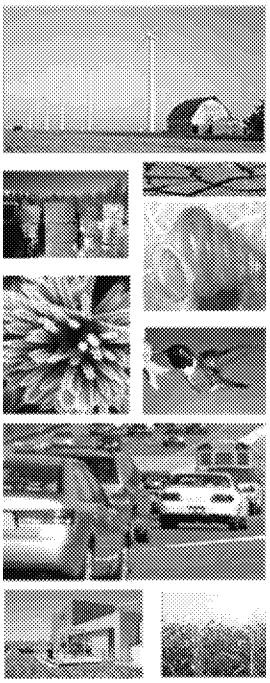
ORD Mission Statement



- Perform research and development
- Provide technical support
- Integrate the work of ORD's scientific partners
- Provide leadership in addressing emerging issues and in advancing the science of risk assessment

ORD's mission is to:
Perform research and development to identify, understand, and resolve current and future environmental problems
Provide responsive technical support to EPA
Integrate the work of ORD's scientific partners (other agencies, nations, private-sector organizations, and academia)
Provide leadership in addressing emerging environmental issues and in advancing the science and technology of risk assessment and risk management
Note that risk assessment is specifically mentioned in the mission statement.

For instructor reference:This is the mission statement from the ORD website.

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The next several slides cover definitions and terminology related to the four primary components of the risk assessment paradigm.

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Important Risk Assessment Definitions:
Hazard

The inherent toxicity of a compound. Hazard identification of a given substance is an informed judgment based on verifiable toxicity data from animal models or human studies.

(EPA's Glossary of Terms of the Environment)

RAB 101 88

There are multiple definitions for hazard, but in general, hazard addresses the question, "what kind of harm are you dealing with?"
Hazard identification determines the nature of effects produced by an agent. Does the agent or chemical cause cancer or reproductive changes?
Hazard / agent / stressor may be used synonymously. Human health risk assessors usually prefer hazard or agent depending on the specifics of the risk assessment.
Some definitions consider "hazard" to be the description of the harm caused. For example the toxicity value associated with a particular compound.
Your reading packet has many definitions for hazard from the EPA thesaurus.

For instructor reference:
ATSDR – Agency for Toxic substances and disease registry
The Codex Alimentarius (Latin for "food code" or "food book") is a collection of internationally recognized standards, codes of practice, guidelines and other recommendations relating to foods, food production and food safety. Established in 1963 by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO)

Another example of inherent property:
Inherent property of an agent or situation having the potential to cause adverse effects when an organism, system or (sub)population is exposed to that agent. (IPCS/OECD 2004)
International Programme on Chemical Safety / Organisation for Economic Co-operation and Development (OECD)
This last example definition brings in the concept that an exposure is required for harm to happen.

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Important Risk Assessment Definitions:
Exposure

Quantified as the amount of an agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut).

From EPA's IRIS Glossary

Exposure answers the question "how much do we have?"
Contact is required for exposure, and without exposure, there is no dose.
Contact is made between the chemical, physical, or biological agent and the outer boundary of the organism. The outer boundary might be the skin, lungs, or gut.
A concentration in the environment doesn't become a dose until exposure occurs.

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Important Risk Assessment Definitions:

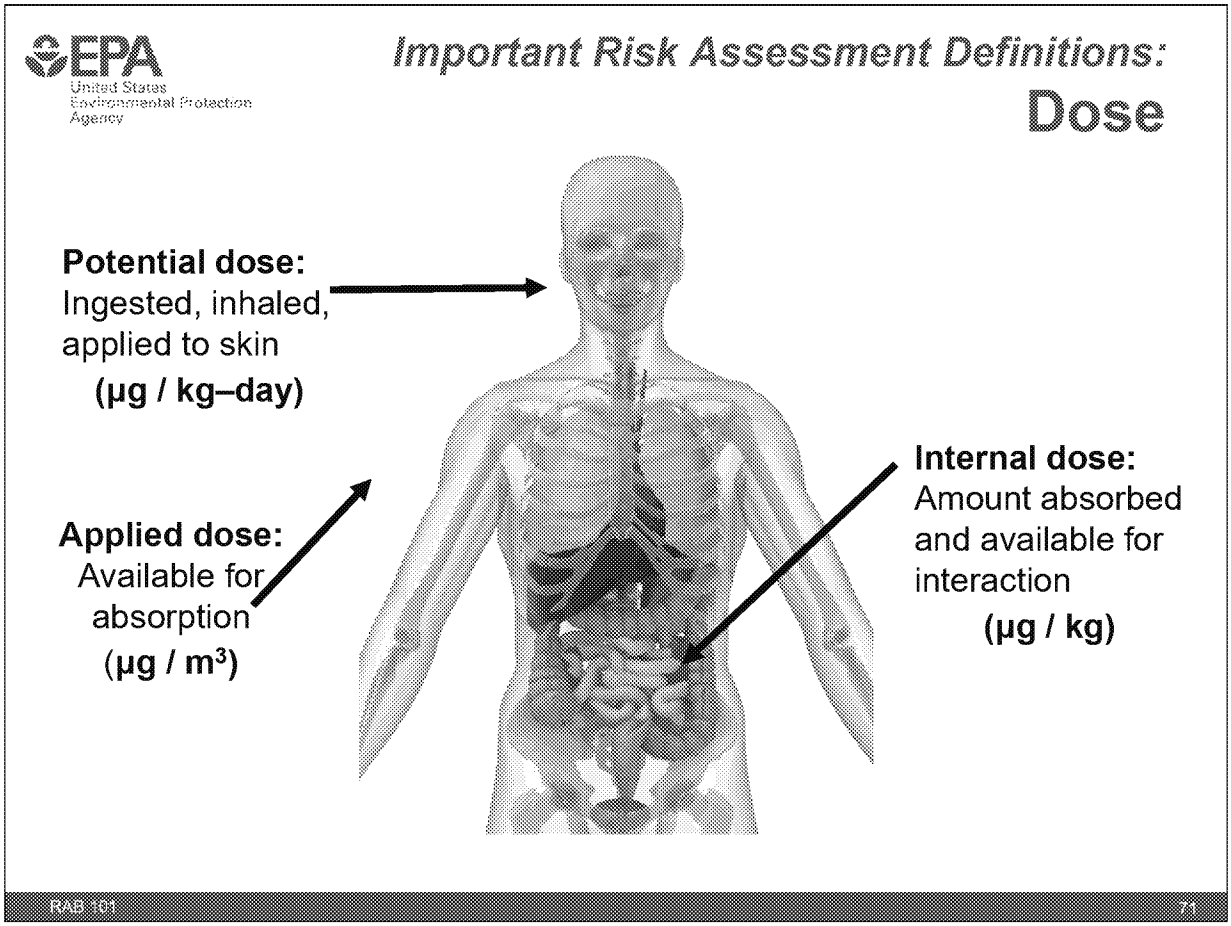
Exposure Assessment

- Identifying the pathways by which toxicants may reach individuals, estimating how much of a chemical an individual is likely to be exposed to, and estimating the number likely to be exposed (EPA's Terms of Environment).
- The determination or estimation (qualitative or quantitative) of the magnitude, frequency, or duration, and route of exposure (EPA's Exposure Factors Handbook).

An exposure assessment looks at how much is out there and coming in contact with a person.

An exposure assessment considers the:
Exposure pathway - The risk associated with exposure to a chemical agent or a mixture of chemicals via a specific pathway (e.g., inhalation of outdoor air).
So pathway includes route and media and in some cases sources as well.
Exposure route - The way a chemical enters an organism after contact (e.g., by ingestion, inhalation, dermal absorption).
Exposure media - Material (e.g., air, water, soil, food, consumer products) surrounding or containing an agent.
Media is captured in pathway.
Exposure source - An entity or action that releases a stressor to the environment (or imposes a stressor on the environment).
Origin of an agent.

Another important concept is that exposures have magnitude (dose), frequency (daily, event based), duration (if event-based, maybe minutes, if daily, maybe over a lifetime), and size of population exposed.



A definition for dose is included in many different EPA documents:
Exposure Factors Handbook
Glossary of IRIS Terms
Guidelines for Carcinogen Risk Assessment 2005
Air Toxics Risk Assessment Reference Library
Definition from the IRIS glossary: The amount of a substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism.
Dose answers the questions, "How much do we have?"
The concept of dose becomes somewhat easier to define if specific modifiers are added.
For example, the following terms are defined in EPA's Guidelines for Exposure Assessment:
Applied dose is the amount at an absorption barrier (like the skin, lungs, GI tract) and available for absorption. This dose has not necessarily crossed the outer boundary of the organism. The units are often µg/m3. (Arrow points to air beside figure.)
Potential dose is the amount of chemical ingested, inhaled, or in a material applied to the skin. It's the potential amount of the chemical that could be absorbed if the chemical were 100% bioavailable. This amount is analogous to the administered dose in a dose-response experiment. (Arrow points to facefigure.)
Internal dose is the amount of a chemical that has been absorbed and is available for interaction with biologically significant receptors. (Arrow points to lungs.)

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Important Risk Assessment Definitions:
Dose-Response Assessment

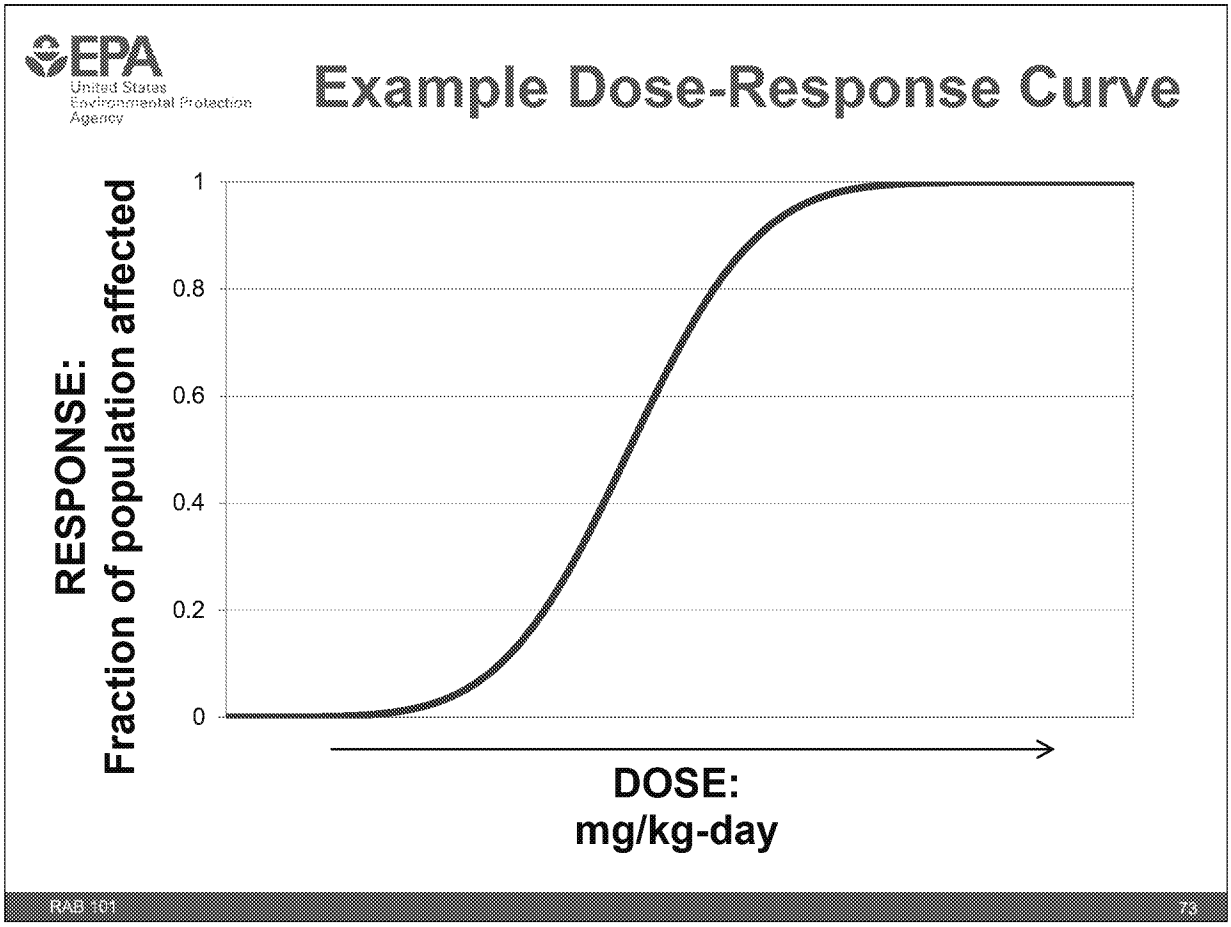
- Evaluating the quantitative relationship between dose and toxicological responses. (EPA's Terms of the Environment)
- A determination of the relationship between the magnitude of an administered, applied, or internal dose and a specific biological response.

  Response can be expressed as:
  - Measured or observed incidence or change in level of response
  - Percent response in groups of subjects (or populations)
  - Probability of occurrence or change in level of response within a population. (EPA's IRIS Glossary)

Dose-response assessment is sometimes called "Toxicity Assessment." A dose-response assessment attempts to answer the question, "How much is bad?" and "How much gives what result?"

A key concept in dose-response is that it is a relationship between the dose and the effect seen in humans. This is the basic idea that health responses are not simply yes or no, but there is a continuum of responses.

Note that the term response captures a lot of different ways to look at response:
Incidence of a disease or a condition
Change in level of response (maybe symptom type or level of severity)
Population based
Probability-based



Dose-response assessment is quantitative. Here is an example dose-response curve showing the fraction of people who are likely to exhibit a given effect at varying doses.

Note that, as you would expect:
at doses close to zero, very few people will be affected
at very high doses, most of the population will exhibit an effect

Note that the slope/shape of the curve varies greatly depending on the specific hazard and effect being analyzed.

For something lots more toxic than this, the curve would be shifted over to the left indicating that a lower doses, more people show a response. For something less toxic, the curve would be shifted to the right.

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Important Risk Assessment Definitions:

Risk Characterization

- The last phase of the risk assessment process that estimates the potential for adverse health or ecological effects to occur from exposure to a stressor and evaluates the uncertainty involved.

(EPA's Terms of Environment)

- The integration of information on hazard, exposure, and dose-response to provide an estimate of the likelihood that any of the identified adverse effects will occur in exposed people.

(*EPA's IRIS Glossary)*

Finally, risk characterization integrates the hazard identification, exposure assessment, and dose-response assessment components to estimate the potential for adverse health or ecological effects resulting from exposure.

Uncertainty analysis is also incorporated in the risk characterization component of the risk assessment paradigm. Our uncertainty depends on the data we used in the previous four components of the process. For example, if we used dose-response data for mice and extrapolated those results to humans, our uncertainty will be higher than if we were basing our dose-response assessment on epidemiological or clinical study data. Our uncertainty might be expressed and applied as a number, for example, an uncertainty factor, but it will also be described qualitatively.

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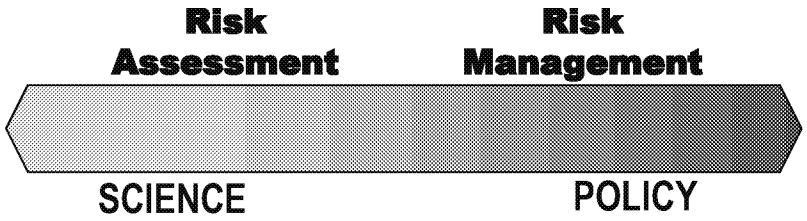
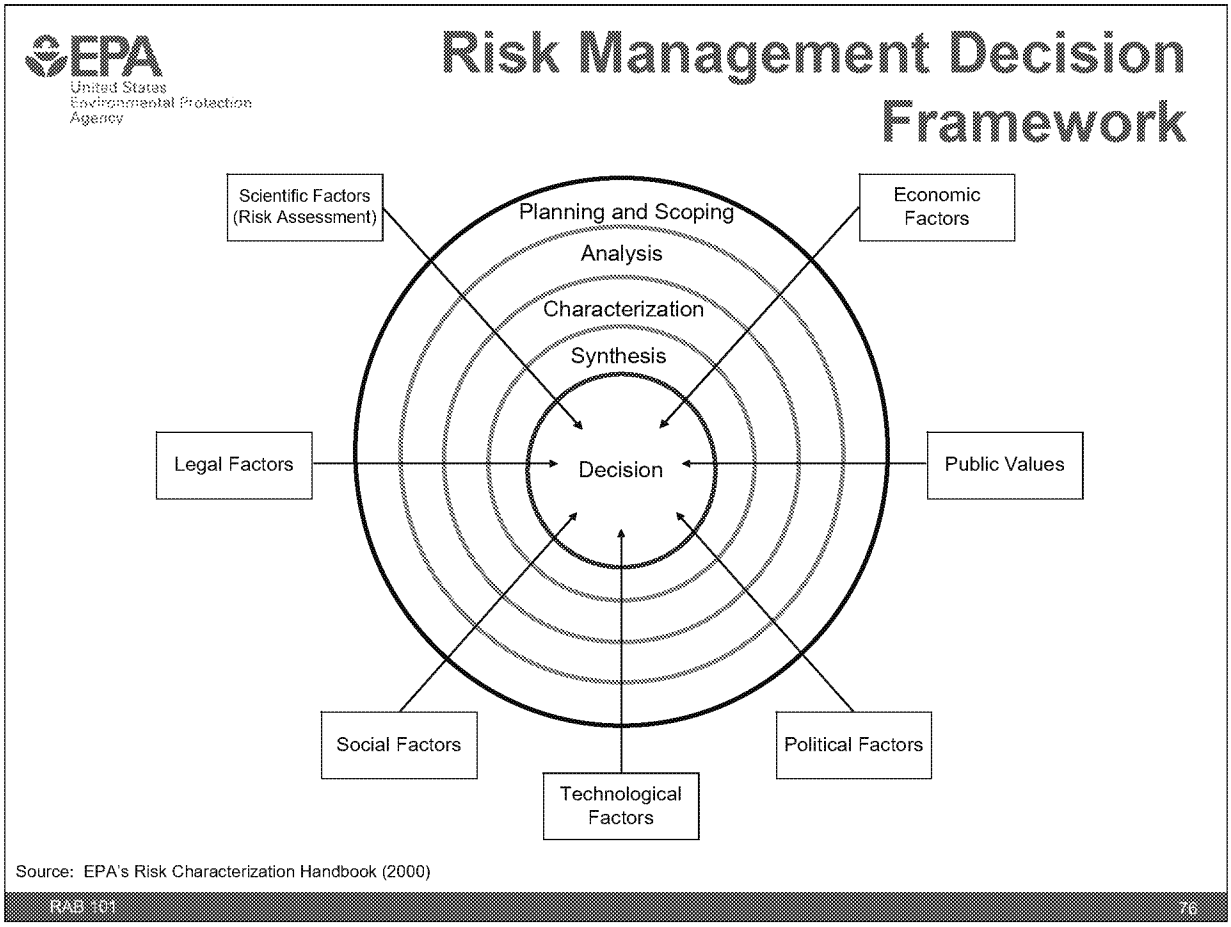
Risk Assessment and Risk Management Are Interrelated

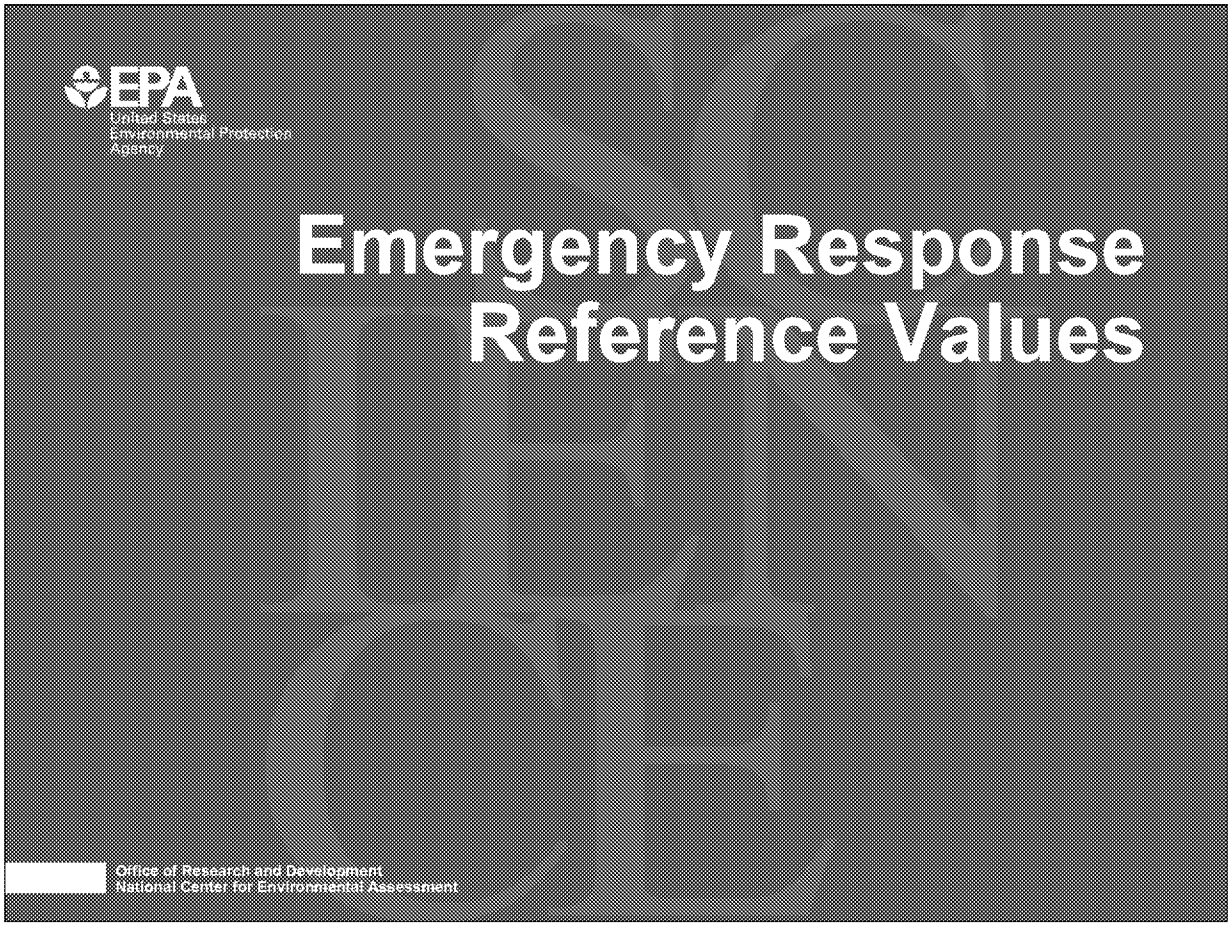


- Risk assessors and risk managers need to have a good sense of when a decision is scientific judgment versus when it is a policy decision informed by science.
- Opinions vary on how separated risk assessment and risk management should be.
- The most current frameworks recommend an iterative process.
- Transparency is key.

Risk assessment and risk management are two components of the risk analysis paradigm introduced earlier (along with risk communication). Recall that the circles for each of these overlap.
In conducting a risk assessment and using the results to make a risk-based decision, there is typically a continuum of decisions ranging from those that are clearly scientific judgment to those that are clearly policy decision. But then there are some decisions that are made during risk assessment that fall in the grey zone. In these cases it may be uncomfortable for either risk managers or risk assessors to claim the decision.
Early on risk assessment and risk management were so interwoven the process lacked transparency. There was a push to separate RM from RA was so that these 2 types of decisions would not be confused. So the separation of RM and RA became very deliberate and as complete as possible.
The current trend, however, is to recognize that the process is iterative, so risk managers and risk assessors communicate and work together but there is also transparency regarding what aspects of the decision and process are risk managements and what aspects are risk assessment.
Risk assessment is a non-linear process, as we saw in the Superfund illustration earlier, and it may be also an iterative process. This involves a dialog between risk assessors and risk managers about the scope of the risk assessment.
Risk assessors and risk managers work together to develop the questions the RA will address.
The iterative process can also include screening level risk assessments that can help pare down the scope of a detailed quantitative risk assessment.
Successive iterations of RA can incorporate new information on risk management options and risk mitigation approaches.
Finally, transparency is "Conducting a risk assessment in such a manner that all of the scientific analyses, uncertainties, assumptions, and science policies which underlie the decisions made throughout the risk assessment are clearly stated (i.e., made readily apparent)." For instructor reference: EPA Air Toxics Risk Assessment Reference Library.
The examples presented at the end of this course illustrate how risk assessment informs risk management.



This figure is adapted from one presented in EPA's Risk Characterization Handbook. It illustrates how risk assessment is just one of the factors that go into risk management decisions.
At least seven factors (represented by the arrows) affect and inform risk management decisions:
Scientific factors (including risk assessment)
Economic factors
Public values
Political factors
Technological factors
Social factors
Legal factors
Each factor passes through four analytical steps to integrate the information for a risk management decision:
Planning and scoping
Analysis
Synthesis
Decision
Each agency goes about risk based decision making in their own way which is appropriate for their context. But whether these factors are specifically acknowledged or not, they probably come into play.



The following are some examples of NCEA products used in risk assessment.

EPA United States Environmental Protection Agency

Emergency Response Values: Applicability

What are the most appropriate applications of emergency response reference values?

(A) To communicate to the general public when chemical concentrations following a disaster might be harmful to human health

(B) To inform workers on a routine basis if chemical concentrations in the workplace are of concern to health

(C) To allow emergency planners to develop systems and policies to prevent and prepare for catastrophic chemical releases

(D) To support laws and regulations mandating chemical concentration levels that result in "acceptable" risk

CLASS ACTIVITY: 8 minutes

**Read the question on the top of the slide
To begin thinking about the appropriate applicability of emergency response values, I am going to ask you to
Read this slide and pick out the key words from each answer (A – D) provided for the question at the top of the slide.
Key words are those that provide clues to whether each answer represents an application that is appropriate for emergency response values.
Using the key words you identified in the answer options, please rank the answers from 1 to 4, with 1 representing the most appropriate application of emergency response values and 4 representing the least appropriate application.
You will have 3 minutes to identify a few key words in each answer that influenced your decision.
We will then discuss the key words as a group. To accomplish this, I'll be looking for volunteers to introduce key words from each of the answer options and defend why they think that particular option is or is not an appropriate application.
**After the 3 minutes is up, call the participants' attention back to the presenter and ask for volunteers to introduce key words for each answer and determine whether the answer they were asked to discuss is an appropriate application for emergency response reference values.
**After the four answers have been discussed, ask another volunteer to provide their ranking for most appropriate application to least.
**Ask the rest of the class if they agree with this ranking.
**After this discussion, emphasize the key words for each of the potential answers.
First, the least appropriate application for emergency response values are answers (B) and (D). Some of the key words that helped us to determine this are as follows:
B) routine, inform, concern
Chemical exposure in the workplace from routine activities is not considered an emergency situation. Emergency response values are not meant to inform those exposed of their current exposures or to strictly delineate a totally "safe" level from levels of concern during an actual emergency exposure; rather, they are tools for risk management. As a result Letter B is one of the two least appropriate applications of emergency response values.
D) legal (or statute or mandating), set, acceptable
Because catastrophes cannot be predicted, they cannot be regulated. As a result, legal statutes cannot be established to control

catastrophic chemical releases; therefore no level can be officially "set" for such a source. Furthermore, "acceptable" risk levels are generally established for regulatory standards that must consider factors other than human health risk in establishing a value – and no legally enforceable standards are established for emergency response values. As a result Letter D is also one of the two least appropriate applications of emergency response values.

And now we can discuss the most appropriate applications for emergency response values. These are contained in answers (A) and (C). Some of the key words that helped us to determine this are as follows:

disaster, communicate, harmful

Emergency response reference values are intended to be applied to a once-in-a-lifetime, or rare, exposure context (i.e., a disaster), and are often used by first responders for emergency mitigation. Although there is generally not time during an emergency situation (i.e., following a disaster) to measure concentrations in the air, concentrations can be conservatively estimated and communicated to the public to determine whether residents in certain areas might experience harmful health effects. As a result, Letter A is one of the two most appropriate applications of emergency response values.

C) catastrophic, prevent, prepare

As discussed, emergency response values are specifically established for catastrophic events to inform emergency planners of chemical concentrations levels during emergencies that might result in specific effects. Awareness of these values allows emergency planners to install control measures that might prevent or quickly mitigate a catastrophic chemical release OR prepare a potentially exposed population or emergency responders for such an event. As a result, Letter C is also one of the two most appropriate applications of emergency response values.

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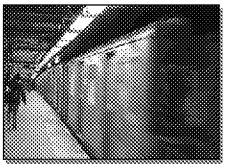
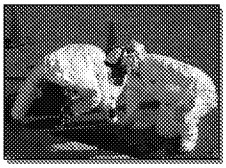
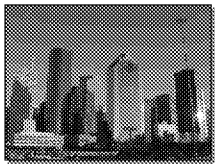
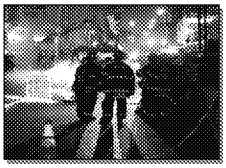
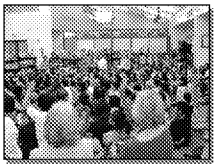
Emergency Response Values: Characteristics

- **Exposure Type:** Workplace or general public
- **Duration:** Generally acute
- **Medium:** Generally concentrations in air (but not always)
- **Enforceability:** Not legally enforceable
- **Applicability:** Inform emergency response and public health planning
- **Adaptability:** Often specify levels of harm

Exposure Type: Can be geared to protect workers or the general public following chemical releases of a catastrophic nature.

Exposure Duration: Because emergencies (e.g., accident or terrorist action) are typically discrete events, exposure durations are typically acute. However, some guidelines do incorporate chronic durations to address long-term contamination resulting from catastrophic events or other duration for locations like spaceships or submarines, where exposures cannot be avoided.

Exposure Medium: Most often expressed as concentration in air; some, however, are expressed as concentrations in water or soil.
Enforceability: As discussed in the activity we just completed, emergency response values are not legally enforceable.
Applicability: Emergency response values act to advise emergency responders and public health officials in risk management. For example, they might allow emergency responders to determine the correct personal protective equipment to wear while responding to an emergency or to determine whether potentially exposed individuals should evacuate or shelter in place.
Adaptability: Emergency response values often specify different concentration levels corresponding to effects that are less and more severe. Such a tiered system is useful to inform responders and health officials for purposes of triage and treatment.

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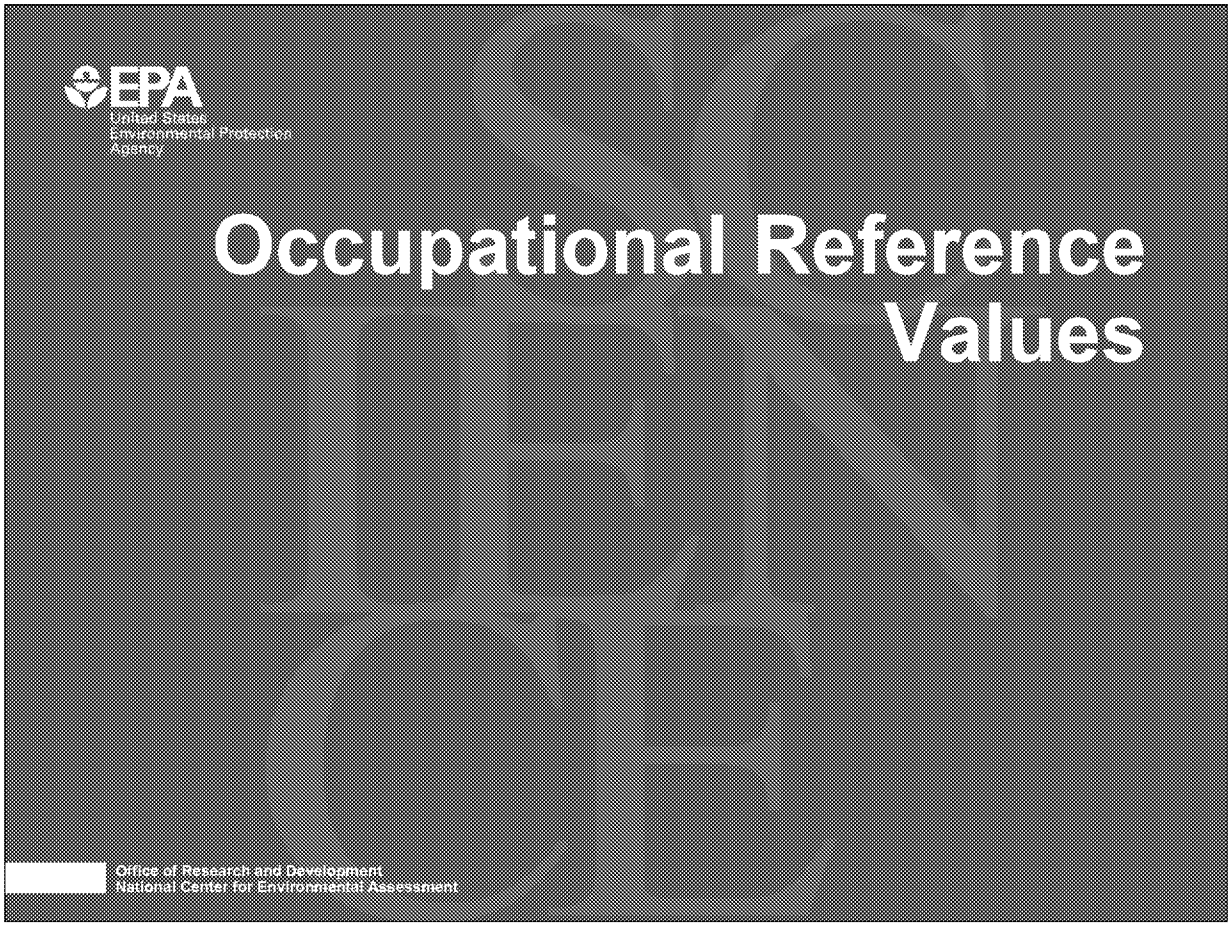
Emergency Response Values: Examples

Guideline	Organization and Context
AEGL Acute Exposure Guideline Level	Developed to describe the risk to humans resulting from once-in-a-lifetime, or rare, exposure to airborne chemicals. *Developed by committee managed by EPA
PAL Provisional Advisory Level	Developed for high-priority hazardous chemicals and chemical warfare agents in air and drinking water following a disaster.
ERPG Emergency Response Planning Guideline	Used in community emergency planning to develop guidelines for responding to potential releases of airborne substances
EEGL Emergency Exposure Guidance Level	Developed for military personnel operating under emergency conditions to prevent irreversible harm or serious impairment of judgment or performance.
EU-AETL European Union Acute Exposure Threshold Level	Used to support emergency-response and land-use planning following accidental chemical releases from industrial facilities.

On this slide there are five examples of reference values developed specifically for emergency response applications. More detail on these values are available in your reading packet.
As you can see, emergency response values are developed by different EPA offices, other federal government entities, not-for-profit scientific associations, and international entities.
These guidelines are developed for a range of situations requiring emergency response planning and management.
Emergency response values might be developed for situations like
catastrophic chemical releases expected to result in exposures to the general public or emergency responders,
exposure to military personnel responding to the release of chemical warfare agents, or
exposures in the workplace following chemical spills.
To understand how emergency response values can actually be employed by first responders to an emergency situation, we'll discuss how emergency response reference values were used to influence evacuation strategies for a chlorine spill that occurred in Graniteville, South Carolina.



The following are some examples of NCEA products used in risk assessment.

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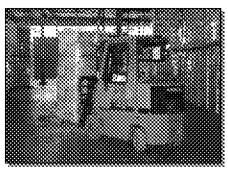
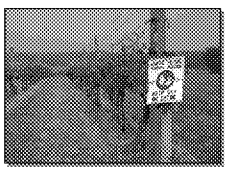
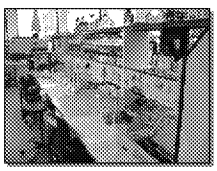
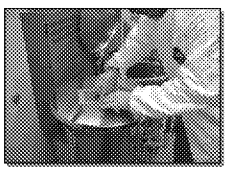
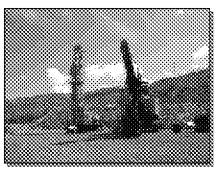
Occupational Values: Characteristics

- **Exposure Type:** Healthy adult workers in occupational settings
- **Duration:** Acute to chronic. Generally include two types of values
  - Not to exceed – "ceiling"
  - Time-weighted average
- **Medium:** Generally concentrations in workplace air
- **Enforceability:** Some are legally enforceable
- **Applicability:** Inform risk management policies in the workplace
- **Adaptability:** Sometimes derived for special environments

Exposure type: Can be geared to protect workers following routine chemical releases or chemical releases of a catastrophic nature.

Duration: Two types of values
Ceiling values are not to be exceeded at any time
Time-weighted average values are not to be exceeded for concentrations averaged over a standard workday (8 or 10 hr) during a normal 40-hour workweek

Medium: Most are expressed as concentrations in air – because the target population is assumed to be healthy adult workers, it is assumed they can avoid oral/dermal exposures.

Enforceability: Occupational values can be mandated under a regulatory statute, and therefore can be enforceable. However, many entities derive occupational values simply as non-enforceable exposure guidelines.

Applicability: Occupational reference values inform decisionmaking in making policies to prevent and respond to exposures within the workplace. Occupational exposure limits are not intended to protect sensitive workers or other populations, and are not intended for the assessment of community air pollution or continuous exposure.

Adaptability: Can be developed for special environments in which exposure cannot be avoided (e.g., spacecraft, submarines).

Occupational Values: Examples

Guideline	Organization and Context
REL Recommended Exposure Limit	Developed for hazardous substances or conditions in the workplace considering a continuous exposure during a normal 40-hour workweek.
IDLH Immediately Dangerous to Life or Health value	Developed only for the purpose of respirator selection under emergency conditions in the workplace.
PEL Permissible Exposure Level	Mandated to address hazardous substances or conditions in the workplace considering a continuous exposure during a normal 40-hour workweek.
TLV Threshold Limit Value	Developed to enable industrial hygienists to make decisions regarding safe values of exposure to chemical substances and physical agents found in the workplace.
CEGL Continuous Exposure Guidance Level	To protect workers on submarines from chemical exposures in an enclosed and isolated environment.

On this slide are five examples of reference values developed specifically for occupational exposures. More details on these and other occupational reference values are included in your reading packet.
Like emergency response values, occupational reference values are developed by different EPA offices, other federal government entities, not-for profit scientific organizations, and international entities. However, unlike emergency response values, some occupational values are legally enforceable.
Occupational reference values are developed with the intent of informing a range of risk management policies, from installing appropriate control technologies to determining the correct respirator to have on hand at a specific location, to determining the level of personal protection equipment needed to enter certain areas in the workplace.

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Ambient and General Public Values: NC Water Quality Standards

Toxicant	Aquatic Life (µg/L)[1]		Human Health (µg/L)[1,2]	
	Federal Guidelines (all waters)	NC Class C Waters[3]	Federal Guidelines (all waters)	NC Class WS-I Waters[4]
Aldrin	--	0.002	0.000050	0.00005
Arsenic	150	50	0.018	10
Chlordane	0.0043	0.004	0.00081	0.0008
DDT	0.001	0.001	0.00022	0.0002
Dieldrin	0.056	0.002	0.000052	0.00005
Endosulfan	0.056	0.05	62	--
Endrin	0.036	0.002	0.059	--
Heptachlor	0.0038	0.004	0.000079	0.00008
Lindane	--	0.01	0.98	--
Nickel	52	88	610	25
Toxaphene	0.0002	0.0002	0.00028	--

Sources: http://epa.gov/waterscience/standards/wqslibrary/nc/nc_4_denr.pdf and http://www.epa.gov/waterscience/criteria/wqctable/index.html#nc

[1]All standards are chronic duration standards – those in bold are not adopted from EPA recommendations
[2]Human health standards based on a cancer risk of 10-6 for carcinogen and IRIS RfD for noncarcinogens from consumption of water and fish
[3]NC Class Waters: Freshwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife
[4]NC Class WS-I Waters: Freshwaters protected as water supplies which are essentially in natural and undeveloped watersheds

RAB 101 84

Ambient and General Public Values: Water Quality Criteria

- Up to this point, the examples presented in this course have focused on reference values primarily derived to protect human health. Water quality criteria are examples of reference values developed to protect both human health and aquatic life.

In developing these criteria, EPA examines the effects of specific pollutants on plankton, fish, shellfish, wildlife, plant life, aesthetics, and recreation in any body of water.

"Under section 304(a) of the Clean Water Act (CWA), water quality criteria are based solely on data and scientific judgments about the relationship between pollutant concentrations and environmental and human health effects; economic or social impacts do not influence criteria recommendations."

EPA's national recommended water quality criteria provide guidance to states, territories, and authorized tribes in adopting water quality criteria that meet the requirements of the CWA.

They are not regulations themselves and do not impose legally binding requirements on EPA, states, territories, authorized tribes, or the public.

Water quality standards form the legal basis for controls on the amount of pollutants entering water bodies from sources such as industrial facilities, wastewater treatment plants, and storm sewers.

They are also the technical basis for reducing runoff from rural and urban areas.

States and tribes might choose to adopt EPA guidelines as standards, or they might set more stringent standards based on the designated use of the water body.

Two examples of use designations are provided on this slide, which compares EPA guideline values for a subset of toxic substances in freshwaters to North Carolina standards for the protection of aquatic life in class C designated freshwaters and the protection of human health in Class WS-1 designated freshwaters.

Class C waters are those waters that are protected for secondary recreation, while Class WS-I waters are water supplies for consumption from natural watersheds.

As indicated by the blue numbers, North Carolina has adopted more stringent standards for many toxic substances to protect both human and aquatic life.

The exceptions are for nickel and arsenic, and the state must provide a justification for these modifications, after which U.S. EPA must determine whether to approve the modification before the standard can be passed.