EXA 403: Developing Exposure Scenarios and Calculating Dose
Instructor Notes

Course Description: Exposure scenarios are sets of facts, assumptions, and inferences about how exposure takes place that aid the exposure assessor in evaluating, estimating, or quantifying exposure. This course will provide participants with the necessary tools for developing assessment-specific exposure scenarios. Factors that will be considered include: the source(s) of contaminant release, identification of contaminants, transport of contaminants from source to site of exposure, which exposure media are impacted, potentially exposed populations, and all exposure routes and pathways. In some scenarios, the "source of contamination" and the "contaminated exposure media" can be one and the same. For example, a scenario could entail a residence on contaminated soil and the exposure pathway is soil ingestion. In other scenarios, the source of contamination can be distinct from the site of exposure, and there would need to be consideration of source strength, and transport of released contaminants to the site of exposure and impacts to exposure media. An example here would be impacts from a chemical spill. At the site of exposure, the air is contaminated, the soil might become contaminated, and there may be food chain impacts to consider. This course will help participants hone their skills in scenario development and will introduce them to some standard scenarios used in EPA program offices and/or in published exposure assessments.

Expected Course Duration: Approximately 45 minutes

Terminal Learning Objective: Understand what an exposure scenario is and how to develop an exposure scenario

Enabling Learning Objectives:

- Understand key concepts and definitions pertaining to exposure scenarios and why they are important when conducting an exposure assessment
- Define the elements used to develop exposure scenarios, such as exposure setting, exposure pathways and routes, chemical of concern, and population of concern
- Understand the importance of variability and uncertainty when developing exposure scenarios
- Describe common exposure scenarios recommended by EPA

Course Materials

- EXA 403 Reading Packet

Course Overview/List of Slides

TITLE SLIDE

What You Can Expect to Learn from this Class (Slide 1)

- In EXA 401 and 402, we introduced the process for conducting an exposure assessment and the key concepts in exposure assessment, such as dose.
- The purpose of this course is to help you understand an exposure scenario, which is a framework that is used to characterize and quantify exposure and dose.
- During the next forty-five minutes, we will talk about not only what an exposure scenario is, but how to develop one.
- We will discuss the various elements that are important to consider when developing an exposure scenario, such as the exposure setting, exposure pathways, the chemical of concern, the exposed population, and intake and uptake rates.

INTRODUCTION AND BASIC CONCEPTS (SLIDE 2)

What is an Exposure Scenario? (Slide 3)

- EPA defines an exposure scenario as, "A set of facts, assumptions, and inferences about how exposure takes place that aids the exposure assessor in evaluating, estimating, or quantifying exposure."
- It's important to note the difference between an exposure scenario and the elements and components that are used to develop an exposure scenario.
- These elements dictate the terms of exposure to a substance for a selected individual or population. Let's talk about some of these elements
- Source: U.S. EPA (2004a)

What Elements are Encompassed by an Exposure Scenario? (Slide 4)

- This slide lists the elements that characterize an exposure scenario:
  - Exposure setting
  - Characteristics of the chemical of concern
  - Source of contamination
  - Exposure pathway and exposure route
  - Environmental and exposure media
  - Intake and uptake rates
  - Characteristics of the exposed population
- A risk assessor must consider information on each of these elements when developing an exposure scenario.
- We will go into each of these elements in more detail in the following slides.
- Before discussing these elements, however, it is important to understand why scientists develop exposure scenarios.

- Source: U.S. EPA (1992)

Why Do We Develop Exposure Scenarios? (Slide 5)

- Exposure scenarios help the exposure assessor picture how exposure(s) might take place, which is necessary in order to identify the data required to conduct the assessment (U.S. EPA, 1992, p. 72).
- Exposure scenarios provide a framework for quantifying exposure (and thus also risk) by following the chemical from the source of release into the environment to an individual exposed to the chemical.
- Finally, development of exposure scenarios helps the risk assessor consider different, specific types of exposure, such as exposure to susceptible populations such as children and exposure via specific pathways such as air, water, and food.

Example Exposure Scenario (Slide 6)

- The image in this slide depicts an example exposure setting.
- What can you tell me about the exposure setting?
  - Recreational park where children and adults play
  - Factory in the background
- What might be a potential source of contamination?
  - Factory
- What can you tell me about the characteristics of the population of concern?
  - Children
  - Adults
- How might the population be exposed, or in other words, what exposure scenario or scenarios could you envision within this setting?
  - Via inhalation from air polluted from factory
  - Dermally if chemical is deposited from air to grass
  - Orally via hand-to-mouth and object-to-mouth activity if they are playing on contaminated grass
- So, an exposure scenario tells us something about the source of exposure, the individual or population exposed, and the activities in which the population are engaged that might cause them to be exposed to the chemical of concern.

Conceptual Overview of Continuum of Source to Dose to Outcome (Slide 7)

- In earlier classes in the EXA series, we discussed how exposure assessment is one of the four basic components of the risk assessment paradigm.
- We've also discussed how exposure assessment can involve the process of evaluating the dose to an individual or population. To picture where this fits, it's useful to refer to the continuum between source and effect shown on this slide.

- The left side of this figure is what's represented by an exposure scenario, starting with release of the chemical from a source, then continuing through transport to environmental exposure media (such as air, water, food, soil, or dust), and human exposure to the chemical via inhalation, ingestion, or dermal contact.
- A dose will result from exposure. Let's revisit some key dose concepts now as well.
- Source: Williams et al. (2010)

Dose Concepts (Slide 8)

- This slide depicts several dose concepts.
- 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.
- The applied dose is the amount at an absorption barrier (like the GI tract, lungs, or skin) and available for absorption.
- Internal dose is the amount of a chemical that has been absorbed and is available for interaction with biologically significant receptors.
- Source: EPA Exposure Assessment Guidelines (1992)

Exposure is a Critical Component of the Risk Assessment Paradigm (Slide 9)

- So, how do these exposure and dose concepts relate to risk assessment? Why do we need to know this, and how does an exposure scenario fit in here?
- Well, risk is quantified by combining exposure and toxicity. An exposure scenario provides one framework for estimating the exposure component.
- What kind of dose (or exposure) will a risk assessor need to estimate? What expression or units are required?
- This depends on how the human health reference value is expressed.
- An exposure scenario used in risk assessment must provide a framework for each important component for whatever route(s) are of interest.

Use of Dose in Quantitative Risk Characterization (Slide 10)

- In a quantitative risk characterization, the exposure, or dose estimate and a toxicity value are used to develop a quantitative risk estimate.
- In order to carry out this calculation, the dose units need to be compatible and comparable to the units of the toxicity value.
- For example, in the case of inhalation exposure, a cancer risk toxicity value, known as the "unit risk," is often expressed in terms of concentration. In assessing cancer risk from inhalation when there is a unit risk value, we need our exposure value to be

expressed as a concentration. Cancer risk is calculated, then, as the product of an air concentration and this unit risk value. This is shown in the top box on the slide.

- The dose from inhalation, oral, or dermal exposure can also be normalized to body weight.
- Here, in the second box, we have calculated a non-cancer estimate from ingestion of food as a hazard quotient, which is the exposure dose divided by the reference dose (RfD).
- Specifically, the hazard quotient for the ingestion exposure would be expressed as the dose via ingestion in mg of chemical per kilogram bodyweight per day, divided by the RfD in those same units, mg of chemical per kilogram bodyweight per day.
- So, regardless of what "kind" of risk you're evaluating (either cancer risk or non-cancer hazard), the units must cancel out in the calculation. Risk is unitless.
- While you may hear reference to both cancer and non-cancer risk, it is most accurate to discuss cancer risks and non-cancer effects. Cancer risk is unitless and is defined as the probability of incurring (not dying from) cancer during a lifetime. For non-cancer effects, we use a hazard quotient. The hazard quotient is most easily understood as the relationship between the dose calculated for a scenario and a dose of the non-carcinogen that is not likely to be associated with adverse effects over the course of a lifetime, such as a reference dose. The trigger for regulatory activity is often a hazard quotient greater than 1.0. In other words, the goal is to have the exposure dose be less than the dose at which no adverse effect is expected.
- Let's review the simple dose equation again to help us understand the importance of units and to provide a foundation for exploring the required components of an exposure scenario.

Dose Equation (Slide 11)

- The first equation on this slide is the simplified equation for calculating potential dose. By multiplying the potential dose by the fraction of the potential dose absorbed, or the AF (which by definition is equal to 1.00 or less), we can calculate the absorbed dose. The absorbed dose is equivalent to the internal dose.
- When an exposure dose is required in a risk assessment, an exposure scenario will cover all of these parameters.
- It's important to pay attention to the units for the values for each of these parameters. All parameters must be expressed in consistent units, and in some cases unit conversions will be necessary. Also, realize that the final units of either potential or absorbed dose will be mass contaminant per body weight per unit of time as shown at the bottom of this slide. The overall units must cancel to these so that the results make sense.
- Let's look at the parameters of this equation in a little more detail.
- Source: U.S. EPA (1992)

Dose Parameters that Can Vary Over Time (Slide 12)

- These are key parameters in the dose equation that can change over time – concentration, contact fraction, intake rate, and body weight.
  - **Concentration** is the exposure concentration of the substance of interest. This can be a measured or modeled value in mg/m^3 of air or mg/kg of food or other similar units.
  - **Contact fraction** represents the exposure to contaminated vs. uncontaminated media. A contact fraction of 1.0 means, for example, that all of the food consumed (represented by a food intake rate) is contaminated. In this case, a dose will be calculated for intake of a contaminated medium only, and this term does not need to be explicitly included. In other cases, the "intake rate" will refer to the total intake of a medium, and a contact fraction of 0.5 might mean that half of this total intake is contaminated. Note that the dose equation in EPA's exposure guidelines does not include a variable for CF. CF has a value of 1.0 or less and is unitless.
  - **Intake rate** is the rate at which the individual takes in a specific media. This might be an ingestion rate, a dermal absorption rate, or an inhalation rate. Intake rate is expressed in units like mg/day or L/day. Recommended values for intake rates of specific foods such as fruits and vegetables, meat, and fish are provided in EPA's *Exposure Factors Handbook* (U.S. EPA, 2011). We'll discuss exposure factors in greater detail in EXA 406.
  - The **body weight** of the individual is also included so that the dose is normalized to that value. Sometimes the intake rate is already normalized to body weight, so we don't need to have a separate term for body weight in the dose equation. Body weight is typically expressed in kilograms. EPA's recommended body weight value for adults is 80 kilograms.
- All of these parameters in the dose equation can vary over time.
- Sources: U.S. EPA (1992); U.S. EPA (2011)

Temporal Parameters in Dose (Slide 13)

- There are three temporal parameters are included in the dose equation that need to be considered.
- Temporal factors are expressed in units of time, which differ from time dependent variables that vary over time that we just talked about.
- First, **exposure duration** (ED) is the amount of time that an individual or population is exposed to the chemical being evaluated. The ED can be given in minutes, hours, days, or years. For example, to calculate the lifetime average daily dose, it is important to know how many years over the course of a lifetime the individual or population is exposed. For an occupational exposure, a reasonable assumption might be 20 years.
- The **exposure frequency** (EF) refers to the frequency with which the exposure occurs. Common units EF include days/year (e.g., 350 days/yr) or events/day. Consider how the EF would differ if a population is exposed to a contaminant in the water from swimming or from showering. The EF for the swimming scenario might be something like 10 days/ year while the EF for the showering scenario might be close to 365 days/year.

- The **averaging time** (AT) is the amount of time over which exposure is averaged. This value must be equal to or larger than the ED. The units of the AT must be the same as the units of the ED.
- The AT must be consistent with the nature of the potential effects (i.e., the hazard) associated with the chemicals of interest. This can include effects associated with short term (acute) exposures up to chronic, lifetime exposures. For example, if one is calculating the lifetime average daily dose to a chemical, as is the case for cancer risk, the AT would be the number of years that the individual is expected to live (regardless of how many of those years the individual is exposed to the chemical). Historically, the most common assumption for this term has been 70 years. For non-cancer effects, the exposure assessor may set the AT equal to ED.
- Sources: U.S. EPA (1992); U.S. EPA (2011)

CHARACTERISTICS OF AN EXPOSURE SCENARIO (SLIDE 14)

- In the next series of slides, we will discuss the important characteristics or elements of exposure scenarios.

Case Study (Slide 15)

- Here we see an example exposure scenario. A useful exposure scenario will provide the framework for us to estimate exposure (including dose, if appropriate) for this situation.
- Let's take a few minutes first to consider this image.
- What is the source of the exposure?
  - A pile of waste drums spill.
- What happens to the chemical after it has been released into the environment?
  - It volatilizes into the air.
  - It seeps into the soil.
  - It seeps into groundwater.
- How are people exposed?
  - Inhale contaminated air.
  - Drink contaminated groundwater.
  - Eat contaminated crops and animals.
- Note also that there is no means shown in this image by which to contain the spill, and that the spill occurred in proximity to a residential area. Let's break this case study down and discuss the characteristics that should be included in an exposure scenario.

Exposure Setting (Slide 16)

- Let's first consider the exposure setting.
- The exposure setting is the physical setting where the exposure occurs. By identifying the exposure setting, the exposure assessor defines the boundaries of the site and determines the scope and geographic scale of the assessment (U.S. EPA, 1992, pg 73).

- What do you notice about the exposure setting in our case study that could affect how a population is exposed?
  - open, uncontained area
  - farming, livestock
  - humans and wildlife in close proximity
  - prevailing wind
  - groundwater is source of water for residential home
- As we noted previously, this is an area that is populated by both humans and wildlife.
- We can also identify the primary source of the contaminant release to the environment, which is the drum spill.

Chemical of Concern (Slide 17)

- The chemical of concern is the chemical or pollutant to which the individual or population is exposed.
- It is important to know as much as possible about the chemical of concern because its characteristics will help the assessor understand how the chemical will travel in the environment and how it will interact with exposed organisms and environmental media.
- Examples of critical physiochemical properties include molecular weight, physical state, vapor pressure, and solubility.
- The assessor must also consider the concept of source to receptor. In other words, it is important to understand not only the source of the exposure and how much has been (or is being) released, but also the pathway that the chemical of concern takes to the exposed population, as well as the characteristics of that population, or the receptor.
- The amount of the chemical that has been or is being released will affect the magnitude of the exposure and dose to the exposed populations.
- The location of the release is also important, for example if the chemical is released in a contained or uncontained area. Our example exposure scenario would be very different if the spill had occurred in a landfill where there were controls in place to contain leaching.
- We also need to know how quickly the chemical is being released to the environment, how much of the chemical has been released (or will be released), and the concentration of the chemical, particularly if it was part of a solution or mixture.
- Source: (U.S. EPA, 1992, pg 73)

Fate and Transport (Slide 18)

- Upon its release into the environment, a chemical can be transported and transformed. Let's evaluate the potential changes for our case study situation.
- Because the exposure occurred in an open and uncontained area, there is the potential for the chemical to evaporate into the air (assuming that it's volatile).
- We see in the picture that there is a prevailing wind, which tells us that the exposure may not affect just populations in immediate proximity, but also nearby residences,

businesses, and other ecological systems. This means that the concentration of the chemical will likely vary in the environment, depending on how far away from the source the exposure measurement is taken.

- The chemical has also seeped into the soil, so the soil may also include the chemical of concern.
- Finally, the chemical has seeped into the groundwater, which could be the primary source of drinking water for this nearby residential area.
- Source: U.S. EPA (1992)

Environmental and Exposure Media (Slide 19)

- The contaminated soil and groundwater are what we call contaminated media. If humans are exposed to the media, we call this exposure media. If they are not exposed to the media, we could refer to this as environmental media.
- Another way to think about this is by considering direct and indirect exposure.
- Chemicals can be transferred between media. Many chemicals bioaccumulate, or are taken up into organisms. They deposit onto soils and vegetation (such as grass) and bioaccumulate in terrestrial animals. Inhalation by humans of released contaminants is termed "direct" exposure, whereas consumption of the impacted animal foods is sometimes termed "indirect" exposure. For chemicals that are long-lived in the environment and bioaccumulate, the indirect exposure pathways can be substantially more important than the direct pathways.
- In some exposure scenarios, the contaminated exposure medium might be considered the source of contamination. In our scenario, the source to the environment is chemical that spills from the ruptured drums, and it is possible that the drum spill will be "cleaned up," thereby removing the source. However, in some cases the clean-up plan does not entirely remove the chemical of concern. If the plan does not include testing and remediation of the ground water and the ground water was contaminated, this contaminated ground water could become the new primary source of contamination.
- Source: U.S. EPA (1998)

Exposure Pathway and Exposure Route (Slide 20)

- EPA defines the exposure pathway as the physical course within the environment that a chemical takes from the source of the chemical to the exposed individual or population (U.S. EPA, 2004a).
    - The exposure pathway reflects the physical and chemical fate and transport and transformation processes that occur, which we discussed on the previous slide.
- EPA also defines an exposure route, which is the way that a chemical enters an individual or population after contact (U.S. EPA, 2004a).
- The difference between an exposure pathway and an exposure route is confusing. The meanings are not intuitively different, but they are different.
- What exposure pathways, and what exposure routes, do you see in our case study?

  - Pathways: chemical evaporates into the air and is carried by wind and can be deposited in soil, surface water, and crops; chemical seeps into soil and groundwater which may be used as drinking water
  - Routes: ingestion, inhalation, dermal contact
- Instructor: CLICK to display conceptual diagram.
- There are numerous exposure pathways in this scenario and some (but not all) of them are captured in this conceptual diagram. As we noted previously, the substance could volatilize and be transported via air and then be deposited in surface water and plants. In this scenario, there are food chain impacts to consider.
- Livestock such as cows could eat contaminated plants or drink contaminated water, and humans could then eat the cow and be exposed indirectly.
- The substance could also seep into the soil and groundwater.
- Possible exposure routes should also be considered here. Because the substance is volatile, it could be inhaled or deposited in surface water and then ingested. It also seeps into groundwater and soil, so groundwater could be ingested. Contaminated plants and animals could also be ingested. Humans could also be exposed to contaminated soil via incidental ingestion or dermal contact.
- Even though the slide depicts what appear to be "outdoor" exposures, "indoor" exposures also occur through track-in of dust/soil, indoor inhalation of air (through open windows or volatiles from showering).

Intake and Uptake Rates (Slide 21)

- While we are discussing exposure routes, it is also important to consider intake and uptake rates.
- When developing an exposure scenario, the assessor must consider the rate at which a contaminated substance is ingested or inhaled, or the rate of dermal contact that an individual or population has with the media containing the substance. This is called the intake rate.
- So, the intake rate refers to the rate of contact with a contaminated medium. The uptake rate then refers to the rate at which the chemical crosses an absorption barrier after contact has been made.
- An example of an intake rate is 1.4 g/kg per day of fruits and vegetables. An example of an uptake rate is 25%, which means that a quarter of the chemical that comes into contact with the absorption barrier will cross the absorption barrier.
- Source: (U.S. EPA, 2004a, pgs 15 and 17)

More on Intake and Uptake Rates (Slide 22)

- For ingestion, the intake rate is simply the amount of food or water (or other beverage) containing the chemical that an individual ingests during a specific period of time.
- For inhalation, the intake rate is the individual's inhalation rate in volume of air inhaled per unit time.

- Inhalation rates will vary according to activity level, age, physiological properties of the individual, and other elements.
- For dermal exposures, the "intake rate" is the rate of dermal contact between the individual and the chemical. Elements to consider include skin surface area, adherence of contaminated media, time during which dermal contact occurs, and other factors.
- The internal (or absorbed) dermal dose is determined by the rate at which the chemical is absorbed. Along with factors just mentioned, this is a function of contaminant properties. Assuming 100% absorption is the most conservative assumption, and is often the assumption for inhalation and for food ingestion. For contaminants that tend to be tightly sorbed (i.e., high Kow) such as PCBs and dioxin, the rate of absorption is often assumed to be less than 100%. For soil ingestion, for example, an absorption rate of 30% might be used. For dermal contact with dust or soil, an assumption of 3% has been used for highly sorbed organic contaminants.
- Sources: U.S. EPA (2004b); U.S. EPA (1989)

Population of Concern (Slide 23)

- The population of concern is the population exposed to the chemical.
- The population can be composed of humans and/or wildlife, and of one or multiple organisms. The focus of this class is on human exposures.
- The physical characteristics of the individuals or population exposed, including age, body weight, and skin surface area, are critical because they can affect calculation of dose.
- The activities in which the population is engaged, as well as the location of the exposed individuals, are also important to know. The level of activity could affect respiratory rate, which in turn can affect how much of a substance is inhaled. How close the population is to the source of the chemical could also affect the amount of the chemical to which individuals are exposed.
- What can you tell me about the exposed population in our example exposure scenario?
    - Humans and wildlife
    - Workers and residential
    - Some are close to the source of the release, some are further away
- These observations are important in developing exposure scenarios. They help us identify which scenarios are relevant and parameterize those scenarios.

Special Considerations for Human Populations (Slide 24)

- It is important to identify characteristics of the population of concern that can affect the population's exposure opportunities.
- For example, is the general population exposed, or is it a specific worker population that is exposed? The general population includes individuals of all ages and may be exposed for longer periods of time than a worker population. A worker population is also most likely comprised of individuals over the age of 18 years.

- Sensitive subpopulations such as infants, children, and elderly adults also need to be considered in an exposure assessment. These subpopulations may experience greater effects for a given dose than the general population.
- Children's exposure is different than adults' exposure. Children are not just little adults; they have important physiological and behavioral differences. Children may be more exposed to some environmental contaminants because they consume more of some kinds of foods and water per unit of body weight, and have a higher ratio of body surface area to volume than do adults, and have different activity patterns. For example, children may have more opportunities for incidental ingestion of chemicals via hand-to-mouth and object-to-mouth activities (U.S. EPA, 2008).
- Infants also have unique exposure opportunities as many may be exclusively breastfed for at least the first months of life. Different chemicals partition more or less effectively to human breast milk.
- If the chemical of concern is in consumer products, it is important to identify the characteristics of the population using the product. Some products, such as toothpaste, are used by both genders, almost all age groups, and across racial, cultural, and socioeconomic groups. Other products, such as cosmetics or infant toys, are used by specific age groups or genders.
- Fisherman and subsistence farmers may be disproportionately exposed to some chemicals. Fishermen and subsistence farmers may eat more of the fish or crops that they catch or grow, so they would experience disproportionate exposures to chemicals contaminating the fish or crops. The difference in intake rates among these different populations will be discussed in greater detail in EXA 406.
- Specific racial, ethnic, and socioeconomic groups may be disproportionately exposed to certain chemicals due to differences in diets and cultural activities.
- A final consideration is susceptible populations. Susceptibility refers to health status, as opposed to stage of life as in sensitive populations. An example of a susceptible population is asthmatics who are more susceptible to air contaminants.

Variability and Uncertainty in Exposed Populations (Slide 25)

- Variability and uncertainty should be considered when constructing an exposure scenario and when characterizing results of an exposure assessment.
- As we just discussed, the characteristics of a population are important to identify when developing an exposure scenario. Characteristics such as body weight and age will vary within a population. For example, a particular exposure scenario may be constructed around children aged 1-6 years, but even within this well-defined smaller age range, there are differences in body weight.
- Variability refers to true heterogeneity or diversity (U.S. EPA, 2010), and in the context of exposure assessment, we have to consider inter-individual variability, intra-individual variability, spatial variability, and temporal variability (U.S. EPA, 1992).
- For example, an individual's body weight will vary over the course of his or her life, and body weights vary across individuals within a population. Similarly, chemical concentrations will vary over time and by location (U.S. EPA, 1992).

- Uncertainty is defined as a lack of knowledge due to incomplete data or an incomplete understanding of a process. (U.S. EPA, 2010)
- It is often the case that there are insufficient data to characterize the full range of characteristics in a population, to fully parameterize the exposure scenario, or to precisely model the exposure scenario. Each of these instances of lack of data introduces uncertainty to the exposure assessment. In order to be protective of the most exposed or most vulnerable individuals in a population, exposure assessors use conservative assumptions when data are not available (U.S. EPA, 1992).
- We will discuss variability and uncertainty in exposure assessment in greater detail in EXA 406 and 407.

Putting It All Together (Slide 26)

- Over the last series of slides, we described some complex exposure scenarios by considering the exposure setting, exposure pathways and exposure routes, and the exposed population. In addition, we also talked about the important questions to ask about the chemical of concern.
- For our case study, exposure scenarios of interest might include:
    - Incidental ingestion of soil contaminated either directly from the spill or indirectly via deposition from the air.
    - Ingestion of contaminated produce grown in soil affected by the spill
    - Ingestion of contaminated water obtained from a well on the premises
    - Inhalation of chemical volatilizing out of well water (e.g., during showering, following flushing of the toilet)
    - There could be others as well!
- At this point in the assessment, we would be ready to collect the required data for each of the scenario characteristics so that we could conduct the exposure assessment. We'll discuss data collection and parameterization of an exposure scenario in other courses.
- The specific scenarios evaluated for a risk assessment would depend on conditions at the site, activities anticipated to occur (such as whether or not agricultural activities are taking place), and other elements, including perhaps a judgment by the risk assessor regarding which scenarios are more likely to result in higher exposures and associated risks.

USING EXPOSURE SCENARIOS (SLIDE 27)

- Now, let's move on to discuss the context in which EPA uses exposure scenarios.

Example Exposure Scenarios (Slide 28)

- EPA's ORD, the program offices of EPA, and other organizations have developed guidance documents that advise risk assessors on how to conduct an exposure assessment within the context of that organization's assessment or regulatory context. Several such documents include:

- NCEA’s Example Exposure Scenarios document (U.S. EPA, 2004a), developed in part to illustrate how data included in EPA’s Exposure Factors Handbook (2011, 1997) can be used to parameterize exposure scenarios;
  - The Risk Assessment Guidance for Superfund (RAGS) developed by EPA’s Office of Solid Waste and Emergency Response, which provides instructions on conducting a risk assessment at a Superfund waste site;
  - The Air Toxics Risk Assessment (ATRA) Reference Library developed by OAQPS, which provides a general overview and some specific guidelines on conducting exposure assessments for air pollutants;
  - The Office of Water evaluates a limited number of exposure scenarios in developing Ambient Water Quality Criteria (AWQC);
  - Other EPA offices have their own guidance documents and operational procedures that they use when conducting exposure assessments.
- The example and guideline scenarios included in these documents represent commonly encountered exposure pathways that could be of potential concern. Scenarios were developed so that assessors have templates on which to build scenarios that are appropriate for specific assessments.
- In general, the scenarios involve exposures via the ingestion, inhalation, and dermal routes.
- In the following slides, we’ll briefly discuss some of the common exposure scenarios for ingestion, inhalation, and dermal exposure.

Example Ingestion Scenarios (Slide 29)

- Ingestion scenarios are intended to cover routes by which bioaccumulative chemicals might end up in the food chain. However, not all ingestion scenarios will include chemicals that bioaccumulate.
- This might include ingestion of articles grown on a farm or in a home garden, including produce, livestock, and animal products, such as dairy products (milk, cheese) and eggs.
- Drinking water could be a potentially contaminated medium if an individual obtains drinking water from a well at the site, or if the surface water source feeds into the public water supply.
- Fish ingestion is a commonly-evaluated scenario; persistent, bioaccumulative chemicals can accumulate in fish following deposition to the water body and watershed and transfer to fish via diet and direct transfer from the water.
- Sometimes, an incidental ingestion scenario will be relevant, such as consumption of dust or surface soil. Another example of an incidental ingestion scenario that is particularly relevant to children is ingestion of residues on the surface of a toy or other object. The residue can be transferred to the hands and ingested either via hand-to-mouth or object-to-mouth activity.
- Breast milk consumption can also be important for some chemicals such as PCBs or dioxins, which readily bioaccumulate in fat and are transferred in human milkfat to a nursing infant.

- Other important exposure scenarios included by EPA include subsistence farmers, home gardeners, subsistence fishermen, and recreational anglers. We'll talk a little bit more about these scenarios in a few slides.
- Source: (U.S. EPA, 2004a)

Example Inhalation Scenarios (Slide 30)

- Inhalation exposure can also be relevant, either for outside or indoor air (or both), depending on the source and nature of the pollutant.
- Characteristics of the exposed individual/population are important for inhalation because they determine intake rate; individuals in an occupational setting are often assumed to be working harder than residents and so might be assumed to have a higher inhalation and thus intake rate. Personal characteristics also dictate activity patterns, which determine where a person is located and the intensity of the activities the individual is engaged in.
- Source: (U.S. EPA, 2004a)

Example Dermal Scenarios (Slide 31)

- Dermal exposure can be important for some chemicals and exposure settings. Example scenarios involving dermal exposure include contact with:
    - contaminated soil or water by residents (such as children while playing)
    - contaminated soil in occupational settings (e.g., by workers at a hazardous waste remediation site)
    - products that contain chemicals of interest, such as building materials or consumer products.
- For dermal exposure scenarios, the fraction of chemical absorbed through the skin is important. In some cases, there will not be useful data on absorption, and an appropriate approach might be to assume complete (100%) absorption as a first approach. This approach, however, can result in very high exposures (e.g., if the concentration of chemical in the contaminated medium is high), and so it's important to be aware of uncertainty regarding absorption efficiency.
- EPA uses the subsistence farmer and home gardener in standard dermal exposure assessments because of the potential that these individuals will come into contact with contaminated soil.
- Source: (U.S. EPA, 2004a)

Common Exposure Scenarios for a General Population Human Health Risk Assessment (Slide 32)

- Depicted in this slide are several standard exposure scenarios that EPA uses in assessments.
- Included in this list are a farmer and a home gardener. In cases where site contamination exists, individuals who are growing their own food in the contaminated area may have higher exposures than those who are eating foods that are more widely distributed.

- Other standard exposure scenarios used by EPA are a subsistence fisher and a recreational fisher. These populations might have higher exposures to chemicals in fish that they catch.
- Source: EPA (2005)

CONCLUSION (SLIDE 33)

- In conclusion, exposure scenarios are a tool for risk assessment that provide a framework for quantifying exposure.

Conclusion (Slide 34)

- An exposure scenario includes information on the exposure setting, the chemical of concern, source of contamination, exposure pathway or pathways and route or routes, environmental and exposure media, intake and uptake rates, and the population of concern.
- EPA has developed various example exposure scenarios that can be used to evaluate ingestion, inhalation, and dermal exposures.
- The example exposure scenarios represent commonly encountered exposure pathways. Assessors should use the representative examples to formulate scenarios that are appropriate to the assessment of interest.
- This concludes EXA 403.
- Source: (U.S. EPA, 2004a)

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