

COAL ASH & TOXICITY, PART 3

How Can People in Our Community Be Exposed to Substances from Coal Ash?

Exposure Pathways

Exposure to a substance happens when someone comes in contact with the substance and it is taken into their body. The way a substance might reach a person and cause exposure is called an **exposure pathway**. For coal ash, possible exposure pathways include groundwater, air, and soil. (See *Coal Ash & Toxicity Part 2* for more information about the substances in coal ash.)

What Does It Mean for an Exposure Pathway to Be Complete or Incomplete?

For an exposure pathway to be **complete** (meaning it results in a person being exposed to a substance), all of these conditions must be true:

1. **Source**: There must be a supply of the substance.
2. **Release**: The substance must be released from the source.
3. **Contact**: A person must come into contact with the substance.
4. **Route of entry**: After contact, the substance must enter a person's body, either by breathing into the lungs, entering the mouth, or by absorption through the skin.

If any of these conditions is not true, then the exposure pathway is **incomplete**. An incomplete exposure pathway means that exposure does not happen in that way.

Exposure Pathways and Coal Ash

For coal ash, potential complete and incomplete exposure pathways involve groundwater, air, and soil. Each of these pathways is described in more detail below, based on the example coal ash sources and communities shown in Figure 1.

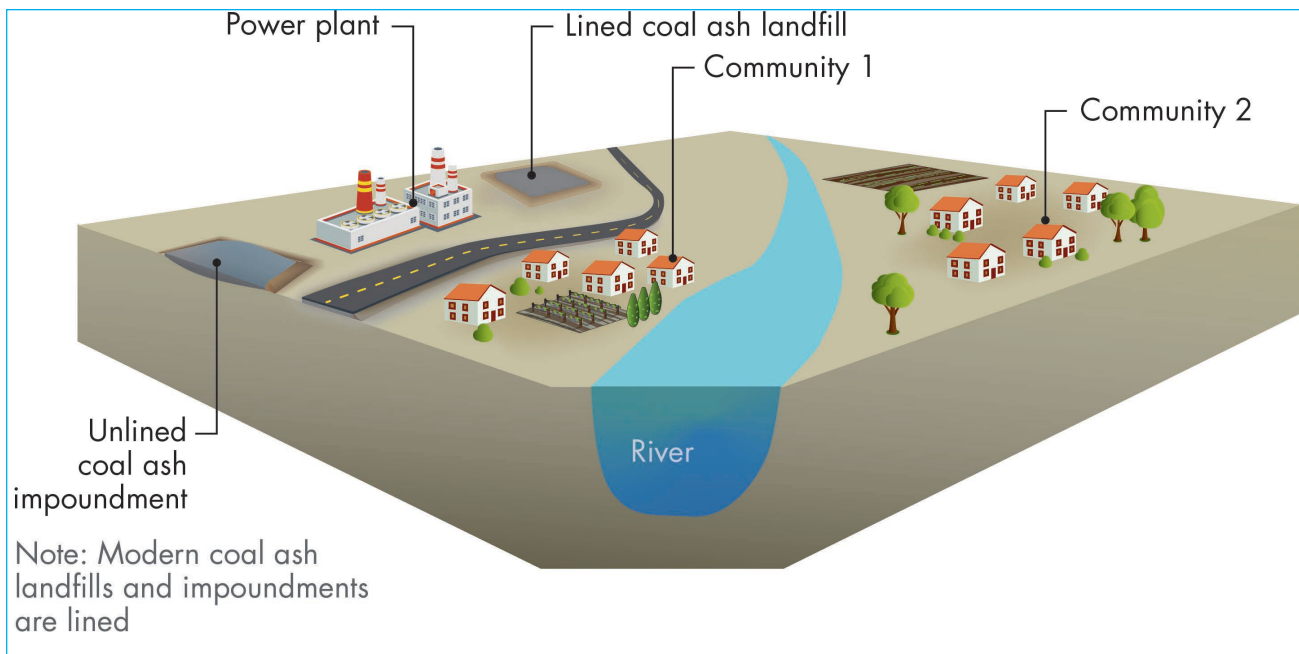


Figure 1. Hypothetical power plant and nearby communities

Groundwater Exposure Pathway

Groundwater is water beneath the earth's surface that slowly flows between grains of soil and within rock fractures. Groundwater is described as flowing from **upgradient** to **downgradient**, just like river water flows from upstream to downstream. A hydrogeologic investigation is needed to precisely determine the direction of groundwater flow, but in general, groundwater flows from areas of higher elevation toward lakes and rivers at lower elevation.

Shallow groundwater (generally less than 100 feet deep) is most important from a risk perspective because it can be directly affected by a release from a coal ash landfill or impoundment. If there is a release from a coal ash source to groundwater, then the release mixes with the shallow groundwater flowing from upgradient (or uphill) and moves toward a lake or river at lower elevation. Shallow groundwater does not flow under major rivers from one side to the other, and typically will not flow beneath rivers or streams unless they are small.

Two examples of complete and incomplete exposure pathways involving coal ash and groundwater are shown in Figure 2. Modern coal ash landfills and impoundments are lined (built with a plastic and/or clay barrier that prevents water from passing through) to reduce the likelihood of significant releases to groundwater. If substances from coal ash do reach groundwater, and if they travel to drinking water wells located downgradient, then a complete exposure pathway can occur from the coal ash source to people drinking the water. However, if the substances don't reach groundwater in the first place, if the drinking water well isn't located downgradient, or if people don't drink the water, then the exposure pathway is incomplete.

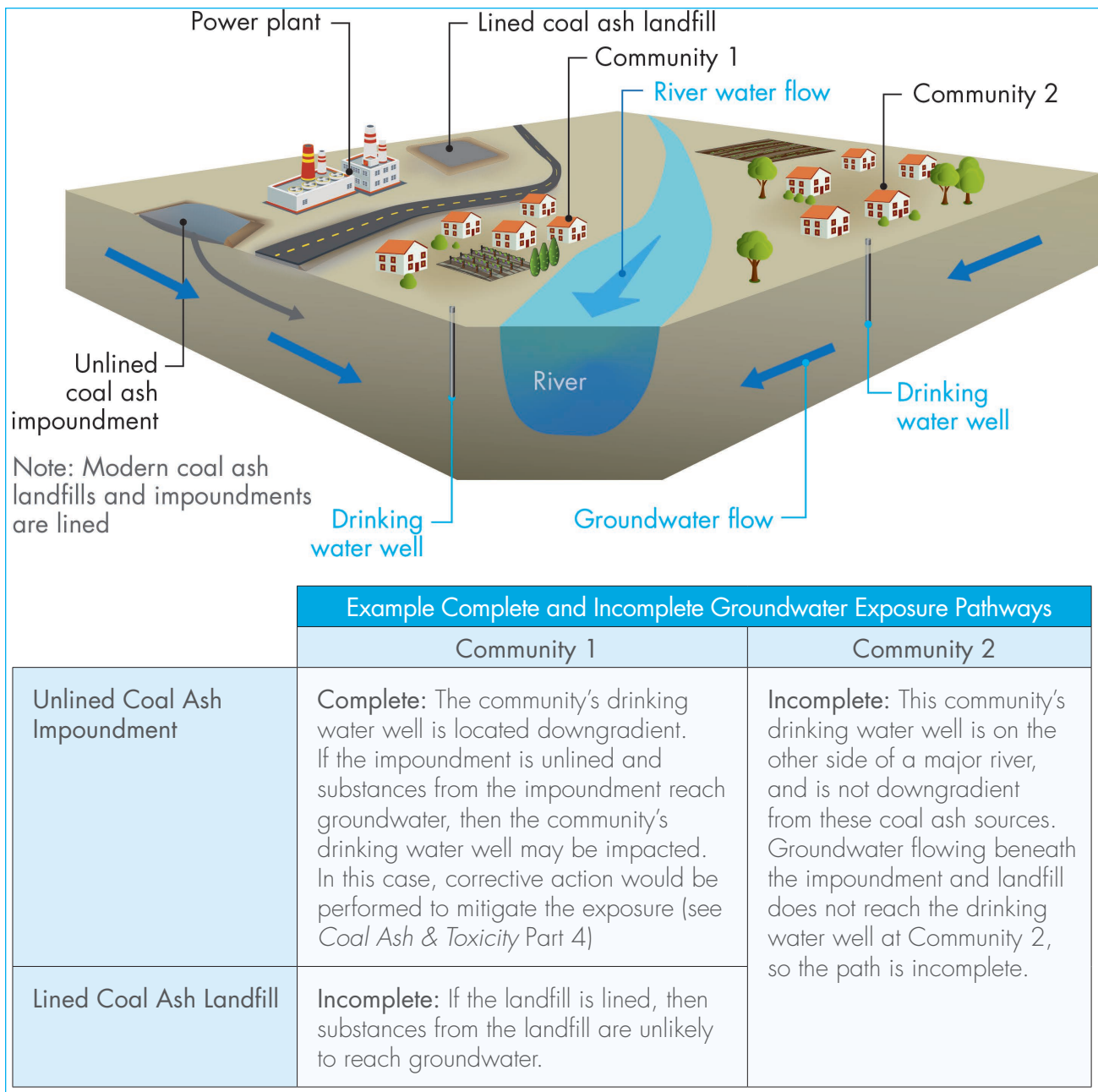


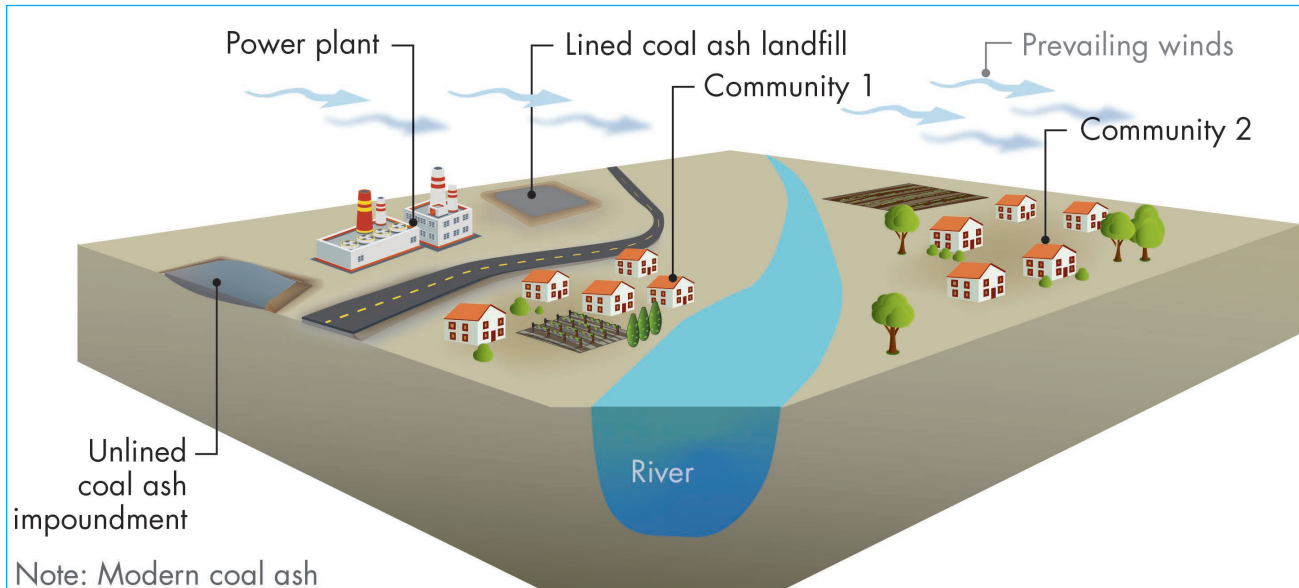
Figure 2. Complete and incomplete groundwater exposure pathways.

Just as the pathway is incomplete for Community 2 because the groundwater passing beneath the landfill and impoundment does not flow there, the pathway would also be incomplete for a community upgradient (uphill) from the power plant or for a community along the river a far distance (such as a mile or more), because the groundwater does not flow to these places. It's also important to note that many of the substances found in coal ash, such as iron and manganese, are also naturally found in soil and groundwater, including in drinking water wells located upgradient from coal ash sources. Finding these common substances when testing well water does not mean that they came from a coal ash source.

Air Exposure Pathway

Just as groundwater can carry substances from upgradient to downgradient, wind can carry particles suspended in the air from **upwind** to **downwind**. Wind direction varies much more than groundwater flow, but the winds in a given place usually tend to come from one direction, called the **prevailing wind direction**, and sometimes from other directions.

Figure 3 shows some examples of complete and incomplete exposure pathways involving coal ash and air.



Note: Modern coal ash landfills and impoundments are lined

Example Complete and Incomplete Air Exposure Pathways		
	Community 1	Community 2
Unlined Coal Ash Impoundment	Incomplete: Wet coal ash particles in impoundments stick together, so that wind cannot carry them to this community.	Incomplete: This community is too far away for wind to carry coal ash particles from these sources to this community.
Lined Coal Ash Landfill	Potentially Complete: If dust control measures are not implemented, then wind could carry some coal ash particles from the landfill to this community.	

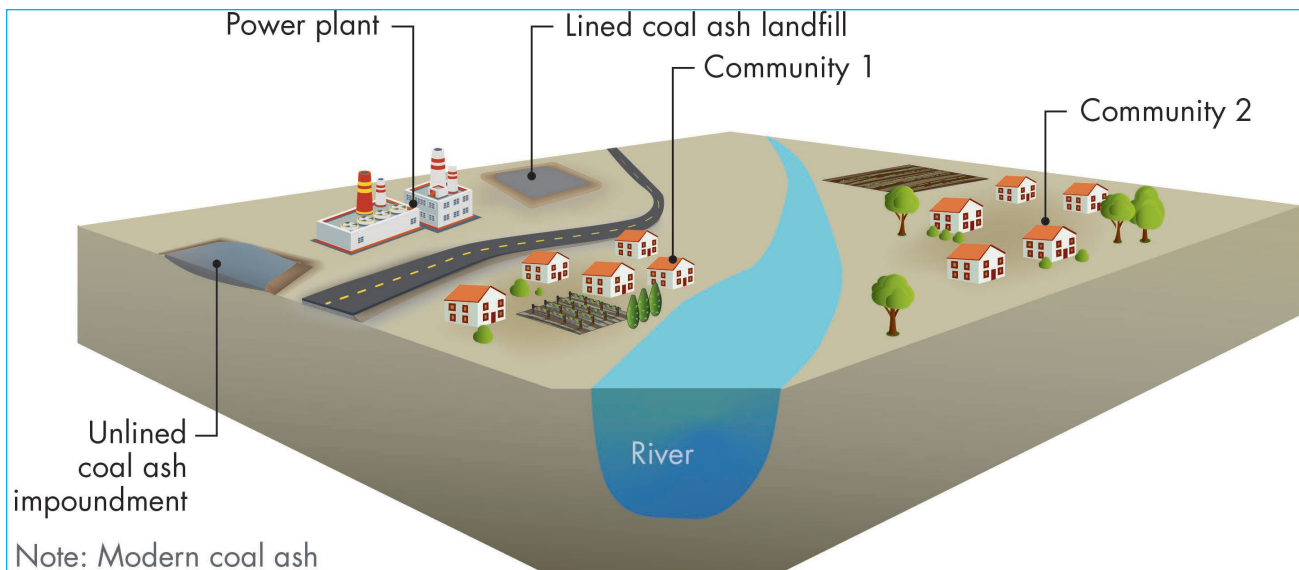
Figure 3. Complete and incomplete air exposure pathways.

Figure 3 shows some examples of complete and incomplete exposure pathways involving coal ash and air. Coal ash landfills and impoundments are covered (or **capped**) when they are closed, which eliminates the air exposure pathway. Before closure, wind can pick up and carry particles from uncovered portions of landfills. This exposure pathway is only possible during operation, before the landfill is covered. In the United States, the Environmental Protection Agency (EPA) requires that all active coal ash landfills plan for and implement dust control practices such as spraying water on landfills (since wet coal ash particles stick together and are not carried by wind) and applying temporary covers to areas that are temporarily not in use. If dust control were not implemented, then wind could lift coal ash particles from the surface of the source and carry them downwind. How far these coal ash particles would be transported before falling to the ground would depend on the size of the particles and the strength of the wind. If these particles reach people, they might be breathed in, depending on their size. If these particles are deposited on the ground near people, exposure through soil could result. (See the next section for more information about exposure through soil.) Even if dust control is not performed and particles are transported by the wind, the air exposure pathway is still incomplete if the particles do not reach people, or if they are not breathed in.

Soil Exposure Pathway

Coal ash particles carried by the wind or by surface water can reach nearby soil. If people then come into contact with this soil, either by touching, inhaling, or swallowing it, this could be another potential exposure pathway. If the particles don't reach the soil, or if people don't come into contact with the soil, this would be an incomplete exposure pathway. Figure 4 shows some examples of complete and incomplete exposure pathways involving soil.

Dust control measures (described earlier) are designed to minimize wind-blown accumulation of coal ash on soils. Landfills and impoundments are also designed and maintained to capture runoff water and confine it to the perimeter of the unit, so this pathway is incomplete. A potentially complete soil exposure pathway could involve trespassers reaching the uncovered surface of the landfill. Fencing is typically erected to limit this exposure pathway.



Note: Modern coal ash landfills and impoundments are lined

Example Complete and Incomplete Soil Exposure Pathways		
	Community 1	Community 2
Unlined Coal Ash Impoundment	Incomplete: Impoundments contain wet coal ash particles, which stick together, so that the wind does not carry them to the soil in this community. Runoff is also contained.	
Lined Coal Ash Landfill	Potentially Complete: Dust and runoff controls are used to prevent coal ash from mixing with soils outside the perimeter of the landfill. However, wind could carry some coal ash particles from the landfill to the soil in this community. Trespassers could also reach the uncovered coal ash surface and be exposed.	Potentially Complete: This community is too far away for coal ash particles from these sources to reach the soil in this community. However, trespassers from this community could reach the uncovered coal ash surface and be exposed.

Figure 4. Complete and incomplete soil exposure pathways.

Estimating Exposure

An exposure assessment is conducted to estimate the total exposure that a person might have to substances from coal ash. (See Parts 1 and 4: *Coal Ash & Toxicity* for more information about exposure assessment) An exposure assessment usually looks at the total of three **routes** of exposure, illustrated in Figure 5:

- **Inhalation** (breathing airborne particles). For substances in coal ash, this route of exposure can occur if the air exposure pathway is complete. Particles that are inhaled may land in the nose or throat and then be swallowed. Particles that enter the lungs may then be cleared from the lungs and swallowed. Particles that are swallowed become part of the ingestion route of exposure described next.
- **Ingestion** (swallowing of substances). For substances in coal ash, this route of exposure is generally most important, particularly if the groundwater exposure pathway is complete. This route of exposure may also occur through soil exposure pathways, if coal ash particles are transferred from the hands to the mouth, reach the gut, and are absorbed into the blood stream.
- **Dermal** (skin contact with substances). For substances in coal ash, this route of exposure can occur if any of the exposure pathways are complete. Examples include skin contact with particles from air, swimming or showering in groundwater from an affected well, and skin contact with soil.

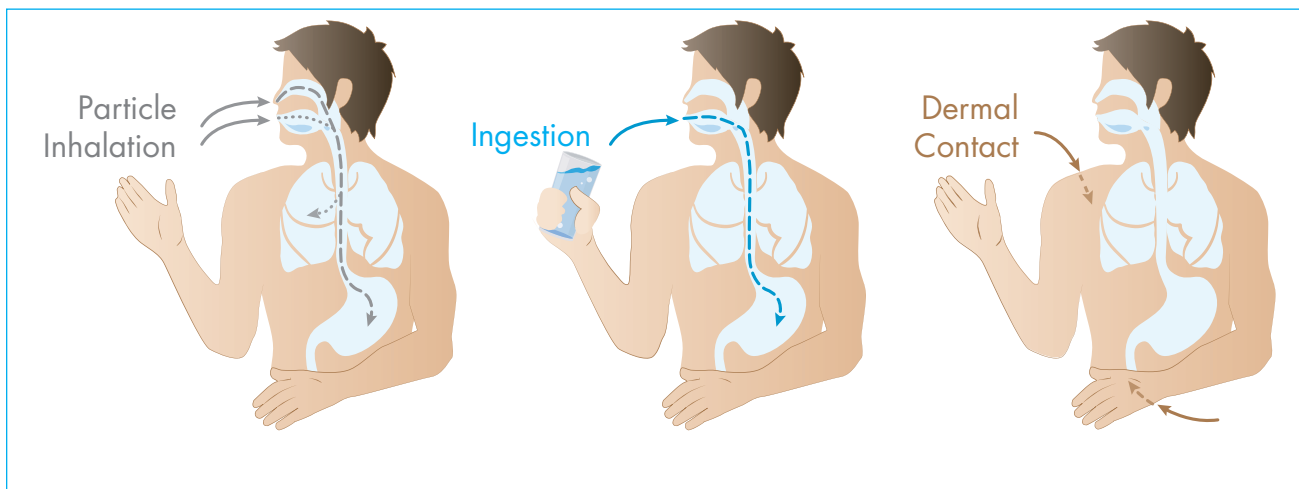


Figure 5. Routes of exposure.

Depending on the substance, exposures from different routes may result in different health effects or could contribute to the same health effect. Considering exposures from all three routes provides a complete picture of exposure so that potential risk can be estimated to protect current and future populations.