United States Environmental Protection Agency
Office of Solid Waste and Emergency Response
Publication 9230.0-05FSb
September 1992

EPA

Superfund Fact Sheet: Exposure Pathways

Office of Emergency and Remedial Response
Hazardous Site Control Division (5203G)
Quick Reference Fact Sheet

Method of Exposure

A hazardous substance is a threat to human health only if people are exposed to it. Exposure happens only if the following three conditions are met. The substance must be:

- released from its containment;
- transported by some means (e.g., air, water, the food chain) from its source to human beings; and
- taken into the human body by breathing, eating or drinking, or contact with the skin.

How a hazardous substance travels from safe containment to, and into, human beings is its exposure pathway.

Containment and Releases

Safely stored, a hazardous substance presents no problem. To use a household example, mercury is a toxic metal. Securely contained in a glass thermometer, most of us keep it in our medicine cabinets and confidently put it into our children's mouths.

By the same principle, hazardous substances properly stored at a site pose no problem to the public. When there is a leak in the containment of a hazardous substance, a potential problem develops. Such breakdowns in containment are generally referred to as "releases" or "spills."

By the time EPA gets involved in a Superfund site or responds to an emergency, a release usually has occurred. In addition to supervising the cleanup of the site, EPA must investigate all potential exposure pathways, and collect information to assess the risk posed by the release to people on and near the site.

In assessing risk, EPA investigators determine what chemicals have been released, in what quantities, and over what period of time. Different chemicals pose different kinds of risk; different chemicals persist in the environment for different lengths of time. The nature of the chemical and the reactions it goes through after release give investigators clues about which exposure pathways it may take to people.

Transport

Unless people are working directly with a hazardous material, or come across an illegal dumping ground, it is unlikely that they will be directly exposed to chemicals from a hazardous release. Rather, the released chemicals will have to be transported through a pathway—air, water, soil, or the food chain—from its source to where people live, work, or play. More than one mode of transport may be involved for any release. By tracking all possible pathways from the source to the population, EPA investigators can begin to assess the risk associated with a release.

AIR pathways can begin with a release of a volatile chemical or by wind-blown contaminated dust. This is a SOIL-AIR pathway. Carried by the wind, contaminants can reach human beings directly or may reach animals to establish a potential AIR-FOOD pathway. Airborne contaminants may also be deposited into surface water (for example, ponds or rivers) to establish an AIR-SURFACE WATER pathway.

SOIL pathways begin with a spill onto the ground or as a release from buried contaminants. Direct exposure can come from eating or touching contaminated soil. If the contaminated soil supports edible plants, a potential SOIL-FOOD pathway may be established. Or, as mentioned above, contaminated dust may establish a SOIL-AIR pathway. Usually, liquid contaminants or contaminants washed from the soil by rainwater migrate through the soil into ground water, where they potentially establish a SOIL-GROUND WATER-DRINKING WATER pathway. Or, contaminated material may run off the soil into lakes or rivers. There it may also potentially contaminate drinking water, or, if the water is used for irrigation, watering animals, or fishing, a SOIL-WATER-FOOD pathway can result. A SOIL-WATER-AIR pathway can even be possible when contaminated drinking water is turned to steam, as in a shower, and the possibility of inhaling the vapor is created.

Often the kind of chemical involved helps make clear what pathway the release will take initially.

Volatile organic compounds and pesticides are most likely to evaporate and to be transported by air. Volatile organic compounds, or VOCs, are composed primarily of carbon and hydrogen and often evaporate into the air from water or soil, although they can also be found in ground water. Non-volatile organic compounds and toxic metals are more likely to contaminate the soil than the air and either sink through the soil into ground water or run off the soil into surface water.

Once in surface water, chemicals may behave differently. Some may re-evaporate into the air; others, such as zinc or mercury, may sink into the mud, stones, and other materials (also known as sediment) at the bottom of a stream or pond. The small animals living in sediment that serve as food for fish and water-birds may all become contaminated, thus continuing the SEDIMENT-FOOD pathway.

Characteristics of the site provide important clues to the most likely exposure pathways released chemicals will follow. Site characteristics and questions such as the following may help to guide EPA's investigation:

Access. If the site has not been fenced or guarded, could people have been directly exposed to contamination or have exposed others, by raising dust or carrying contaminated soil home on their shoes or clothes?

Geology. Does the geology beneath the surface soil of the site offer a route for the chemical contaminants to reach ground water?

Hydrology. If the spill could have seeped into ground water underneath the site, does that

Case Study: Canton, Mississippi

Southeastern Wood Preserving in downtown Canton, Mississippi operated from 1928 until early 1979, when its owners filed for bankruptcy and abandoned the site. They left behind three unlined, over-flowing ponds of creosote sludge and water. EPA pumped 30,000 gallons from the flooded areas of the site, but the untreated sludge remained.

In December 1988, while surveying a creek that borders the site, the Department of Agriculture's Soil Conservation Service noticed an oily waste leaching into the creek. Two exposure pathways—one potential, one actual—have been identified in this case. The actual pathway—SLUDGE-SOIL-SURFACE WATER-SKIN CONTACT—leads to a swimming area in a state park a full mile downstream from the site, where children have complained of creosote burns. The potential pathway—SLUDGE-SOIL-GROUND WATER-DRINKING WATER—leads to a municipal well 100 feet from the site. The well has been tested and is not now contaminated.

ground water feed drinking water sources? Does ground water seep into creeks or streams?

Soil. How dense is the soil? Is it sandy so that the spill could have seeped through it? Or is it clay-like, so that the spill would have remained on the surface or run off with rainwater?

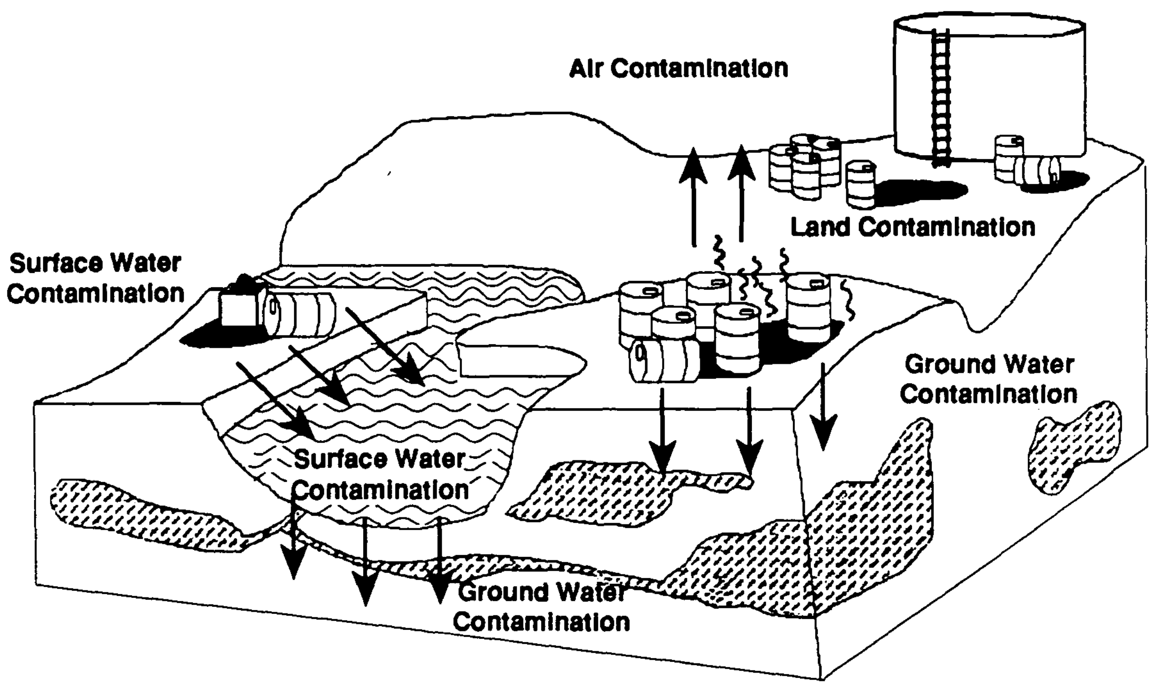
Water. Does running water pass through the site? How fast is it moving? Where does it go?

Vegetation. Is there vegetation on the site that might have kept contaminated dust from blowing? Or could the spill have contaminated a food supply for local animals, so that their meat or milk would be dangerous for human consumption?

Wind, precipitation, temperature, and *humidity* may also be important to the investigation. For example, if the chemical evaporates, the wind will have carried it off-site. Investigators then must consider the prevailing wind or, perhaps, the exact wind strength and direction for particular dates. Airborne particles, wherever the wind has carried them, may be deposited in rain. Rain can also wash surface contaminants down-slope or leach chemicals through more porous soil. Again, investigators may look for clues either in general rainfall statistics or in the records for specific dates.

Given their clues in the form of knowledge of the release, characteristics of the site, and meteorological data, EPA investigators can formulate scenarios of what might have happened. Hypotheses about the pathways that contaminants could have taken is only a first step. Investigators must then confirm or disprove these hypotheses with evidence. Where necessary, they will sample and analyze air (if possible), soils, surface water and

EXPOSURE PATHWAYS



wells (for ground water), fish, and other creatures. Even when contaminants have passed through soil or water on their way to other media, they leave behind traces of themselves, thus making it possible to track the complete pathway and assign responsibility. Sometimes the investigation must work in the opposite direction. Contamination will be found in a well or lake, and the pathway must be tracked back, from the evidence in the environment to its source.

Protection at the Exposure Point

On the other end of the exposure pathway, at the point where a hazardous substance comes into contact with human beings (sometimes referred to as the exposure point), protective measures are necessary.

To begin with ordinary household examples, hazardous products carry warnings that advise their users of protective steps to take. If ingestion is a risk, for example, we are advised to "keep out of the reach of children." If inhalation is a risk, we are advised to "use only with adequate ventilation." If contact is a risk, we are advised to "wear protective clothing."

On a larger scale, when EPA is responding to an emergency or to discovered contamination, protective measures also may be necessary. If the hazardous substance has made its way into drinking water, an alternate source may have to be supplied. If the substance has made its way into the food chain, the consumption of contaminated fish, animals, or milk may have to be restricted. In extreme circumstances (generally, but not always, involving a hazardous substance in the air), people may need to be evacuated and cleanup workers may need to use gas masks and fully-protective clothing.

Summary

Determining how people may be exposed to chemical contaminants from a Superfund site or an accidental release is complicated. The air, soil, ground water, and surface water are all potential pathways for contaminants to travel once they are no longer safely stored.

EPA investigators are skilled at tracing the paths chemicals take once they are spilled or released from storage. The Superfund Program has established proce dures to protect people from exposure to hazardous substances. In this way, Superfund is able to meet its Congressional mandate to protect human health and the environment from the effects of uncontrolled releases of hazardous materials.

Case Study: Cherokee County, Kansas

Cherokee County, Kansas, has been a lead and zinc mining center for over a century. Piles of waste from mining processes (mine tailings) cover the surface, and old mine shafts and pits honeycomb the subsurface for thousands of acres. The nature of the mining operations, the extent of the site, and the impossibility of closing off the area create a very high number of potential exposure pathways.

Radon gas releases create a potential AIR pathway. Stirred up dust from tailings makes a potential SOIL-AIR PATHWAY for toxic metals. Chemicals from the tailings and mine shafts that seep into ground water create a SOIL-GROUND WATER-DRINKING WATER pathway, and many wells are contaminated with lead, zinc, cadmium, selenium, and chromium. Runoff from the tailings into surface water has contaminated fish, creating a potential SOIL-SURFACE WATER-FOOD pathway.

Water treatment systems and temporary alternative water supplies have been provided while the cleanup continues.

EPA is developing the Superfund Accelerated Cleanup Model (SACM) to make hazardous waste cleanups more timely and efficient. This will be accomplished through more focus on the front end of the process and better integration of all Superfund program components. The approach involves:

- A continuous process for assessing site-specific conditions and the need for action.
- Cross-program coordination of response planning.
- Prompt risk reduction through early action (removal or remedial).
- Appropriate cleanup of long-term environmental problems.

SACM will operate within the existing statutory and regulatory structure. As SACM develops, there may be modification of certain policies noted in this fact sheet. However, overall priorities will remain the same: deal with the worst problems first; aggressively pursue enforcement opportunities; and involve the public in every phase of the process.

Regional Superfund Community Relations Offices

Region 1
Superfund Community Relations
Office of Public Affairs
EPA Region 1 (RPA-74)
#1 Congress Street
Boston, MA 02203
(617) 565-3425

Region 2
Community Relations Branch
External Programs Division
EPA Region 2 (2-EPD)
26 Federal Plaza
New York, NY 10278
(212) 264-7054

Region 3
Superfund Community Relations
Office of External Affairs
EPA Region 3 (3EA21)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-9905

Region 4
Superfund Community Relations
Waste Management Division
EPA Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-2643

Region 5
Superfund Community Relations
Office of Public Affairs
EPA Region 5
Metcalfe Federal Bldg.
77 West Jackson Blvd.
Chicago, IL 60604
(312) 353-2073

Region 6
Superfund Community Relations
Hazardous Waste Mgmt. Division
EPA Region 6 (6H-SS)
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75270
(214) 655-2240

Region 7
Community Relations
Office of Public Affairs
EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7003

Region 8
Community Relations Branch
Office of External Affairs
EPA Region 8 (80EA)
1 Denver Place
999 18th Street, Suite 1300
Denver, CO 80202
(303) 294-1144

Region 9
Superfund Community Relations
Hazardous Waste Mgmt. Division
EPA Region 9 (T-1-3)
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2178

Region 10
Community Relations Section
Hazardous Waste Division
EPA Region 10 (HW117)
1200 6th Avenue
Seattle, WA 98101
(206) 553-6901