The Conceptual Model with Life Cycle Considerations

Green Ribbon Science Panel

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By the Department of Toxic Substances Control

Use of the Conceptual Model in AA

- Graphical depiction
  - Chemical use, release and exposure
  - different product phases
- Starting step for the AA process
  - Useful throughout AA
- Helps identify relevant factors
  - Enhances analytical completeness and transparency

Conceptual Model Example

Chemical X – the Chemical of Concern, a flame retardant in an electronic device casing

Alternative A – chemical substitution for flame retardant

Material B – material replacement for casing

Illustrates:

- Initial exposure during use phase
- Fate & transport with potential exposure implications
- Life cycle considerations for the chemical & alternatives

Why was the CoC listed?

Conceptual model explaining why a Chemical of Concern is listed. A Chemical of Concern is listed based on several hazard traits, and environmental and toxicological endpoints. In this example, Chemical X, a flame retardant, is a concern due to its developmental toxicity, reproductive toxicity, hepatoxicity, digestive toxicity, and endocrine toxicity hazard traits. Chemical X is used in electronic device casings found in the home where it is released via off-gassing, and may adhere to or accumulate on dust particles in the home. Chemical X may also be released from the electronic device casing when it is incinerated at the end of its useful life. During incineration, Chemical X is released to the environment where it bioaccumulates and persists. Chemical X in dust removed from the home may be released to the environment via storm drains where it bioaccumulates and persists. Humans are exposed to Chemical X from household dust, water, or sources in our food chain that ingested water or plant material containing Chemical X.

Chemical X fate and transport

Fate and transport conceptual model showing the amount of Chemical X released to different environmental compartments. City emissions and bio-processes releases Chemical X into the air. The long-range transport of Chemical X via the air consists of wet deposition = 2,500 kilograms/year (kg/yr); dry and wet deposition = 235 kg/yr, and dry deposition = 6,700 kg/yr. The air and water exchange of Chemical X is approximately 0. Releases of Chemical X from e-waste emissions is 9,400,000 kg/yr where 1,960 kg/yr is released via riverine runoff. The outflow to the ocean contains 1,550 kg/yr. Chemical X degrading in the water is 45 kg/yr. The soil contains 44,000 kg where 600 kg/yr is deposited in sediment.

Chemical X fate and transport

Fate and transport conceptual model for Chemical X showing fish and livestock exposed to Chemical X from contaminated water and grass may be ingested by humans via fish, meat and dairy products.

Conceptual Model of Exposure to Chemical X

Flowchart showing potential environmental exposures to Chemical X. Three exposure routes are shown; inhalation, dermal, and oral. Chemical X emitted from electronic device casings via off-gassing and maybe present in household dust which is inhaled. Chemical X may also be inhaled from the outdoor if electronic device casings are incinerated nearby. Chemical X may be released to the environment when household dust is swept outside and into an untreated drain. Dermal contact to Chemical X may occur from direct contact with household dust, such as a baby crawling on the floor. Chemical X may also be ingested if household dust is transferred from your hands to food you are eating or when a baby puts their hand in their mouth.

Fate & Transport of Chemical X

Conceptual model explaining the fate and transport considerations for Chemical X. Chemical X is a concern due to its developmental toxicity, reproductive toxicity, hepatoxicity, digestive toxicity, and endocrine toxicity hazard traits. Chemical X is used in electronic device casings found in the home. As Chemical X is released from the electronic device casing, it may adhere to or accumulate on dust particles in the home. Chemical X may also be released when the electronic device is incinerated at the end of its useful life. During incineration, Chemical X is released to the environment where it bioaccumulates and persists. Chemical X in dust removed from the home may be released to the environment via storm drains where it bioaccumulates and persists. Humans are exposed to Chemical X from household dust, water, or sources from our food chain that ingested water or plant material containing Chemical X.

Fate & Transport of Alternative A

Conceptual fate and transport model for an alternative flame retardant called Alternative A. Alternative A has the following hazard traits: brain and nervous system toxicity, reproductive toxicity, and genotoxicity. Alternative A may be used in electronic device casings found in the home. Alternative A may be released from the device casing and adhere to or accumulate on dust particles in the home. Alternative A may also be released when the device casing is incinerated at the end of its useful life. During incineration, Alternative A is released to the environment and can cause aquatic toxicity if deposited from the air into a water body. Alternative A in dust removed from the home may be released to the environment via storm drains where it can cause aquatic toxicity in animals and fish exposed to the stormwater. Humans are exposed to Alternative A from household dust.

Fate & Transport of Material Switch-Out

Conceptual fate and transport model for a material switch-out. If a different material is used to make the electronic device casing, such as Material B, but still uses a flame retardant, Material B may release this flame retardant to the environment when the device casing is incinerated at the end of its useful life, or emitted from the device casing during use. During incineration, the flame retardant in Material B is released to the environment where it bioaccumulates and persists. The flame retardant in Material B may also be released directly to the environment from the device casing where it bioaccumulates and persists.

Determining Potential Relevant Factors by Life Cycle Stages

Flowchart showing the releases of Chemical X and Alternative A during the "Use" stage of the product's life cycle. Chemical X is released during the "Use" stage where a human may be exposed to the chemical by inhaling dust or ingesting dust transferred from the hands to the mouth. Chemical X has the following hazard traits to consider: developmental toxicity, reproductive toxicity, endocrine toxicity, and hepatoxicity. Alternative A is released during the "Use" stage where a human may be exposed to the chemical by inhaling dust or ingesting dust transferred from the hands to the mouth. Alternative A has the following hazard traits to consider: Nervous system toxicity, reproductive toxicity, and genotoxicity.

Determining Potential Relevant Factors by Life Cycle Stages

Flowchart showing the factors considered when determining a potential relevant factor for the “Use” stage of a product’s life cycle. When comparing Chemical X and Alternative A, disposal and recycling is another life cycle stage identified. As part of the “Disposal and Recycling” stage, incineration, recycling and landfilling are considered. Incinerating Chemical X will release it to the environment where it bioaccumulates and persists. Humans that are exposed to Chemical X in dust or other sources where Chemical X has bioaccumulated may be exposed to its hazard traits (developmental toxicity, reproductive toxicity, endocrine toxicity, and hepatoxicity). For Alternative A, humans are exposed to the chemical during incineration, or after incineration when Alternative A is deposited from the air into water where it causes aquatic toxicity.

Determining Potential Relevant Factors by Life Cycle Stages

A flowchart showing the factors considered for five life cycle stages (raw material extraction, processing and production, use, disposal and recycling, and transportation which is consider as part of the other four stages) for Chemical X and Alternative A.

For the “Raw Material Extraction” stage, Chemical X has bromine mining or distillation with no adverse impacts identified while Alternative A has phosphorus mining with scarce resource depletion identified as an adverse impact.

For the “Processing and Production” stage, the adverse impacts for Chemical X are associated with using more plastic during the casing production compared to the processing Chemical X while the adverse impacts for Alternative A are associated with higher use of Alternative A while producing the casing compared to the amount of plastic used during casing production.

Determining Potential Relevant Factors by Life Cycle Stages (continued)

For the “Use” stage, the adverse impacts during use for Chemical X are developmental toxicity, reproductive toxicity, endocrine toxicity, and hepatoxicity while for Alternative A these are nervous system toxicity, reproductive toxicity, and genotoxicity.

For the “Disposal and Recycling” stage, incineration and recycling are considered for Chemical X and Alternative A. No adverse impacts are identified for either chemical associated with recycling. For incineration, Chemical X has adverse impacts associated with bioaccumulation, persistence, developmental toxicity, reproductive toxicity, endocrine toxicity, and hepatoxicity while Alternative A has adverse impacts associated with aquatic toxicity, nervous system toxicity, reproductive toxicity, and genotoxicity.

Determining Potential Relevant Factors by Life Cycle Stages (continued)

For the “Transportation” stage for the other four life cycle stages, the adverse impacts associated with both chemicals must consider factors such as distance, mode, and weight of the product.

Conceptual Models Help AA

- Visualize the relationships among fate and transport of the chemicals and routes and pathways of exposure
- Clarify similarities and differences among alternatives
- Consider phases beyond the use and disposal phases

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Questions or Suggestions?