After The Flames:

Assessing Environmental Liabilities Following Wildfire Devastation and the Path to Restoration/Reclamation

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Photo: CBC

Introduction

- As of late August, 2023 holds Canadian record for area burned by wildfires (15.2 million hectares and counting) compared to previous (1995) record of 7.1 million hectares.

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Outline

Entreprise, NWT 2023 - Photo: Tammy Gauthier Neal/Facebook

- Wildfires at the Wildland-Urban Interface
- Contaminant Sources
  - Built Environment
  - Response Activities
- Environmental Effects
- Knowledge Gaps
- Wildfire Recovery/Response
- Case Study

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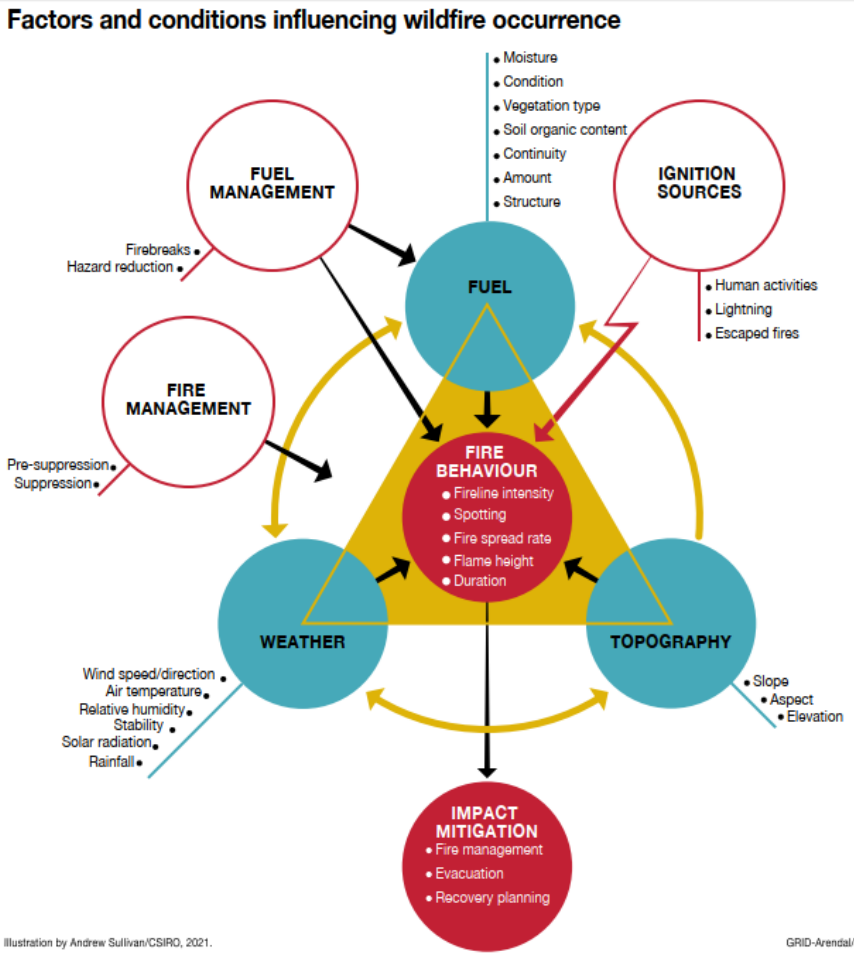
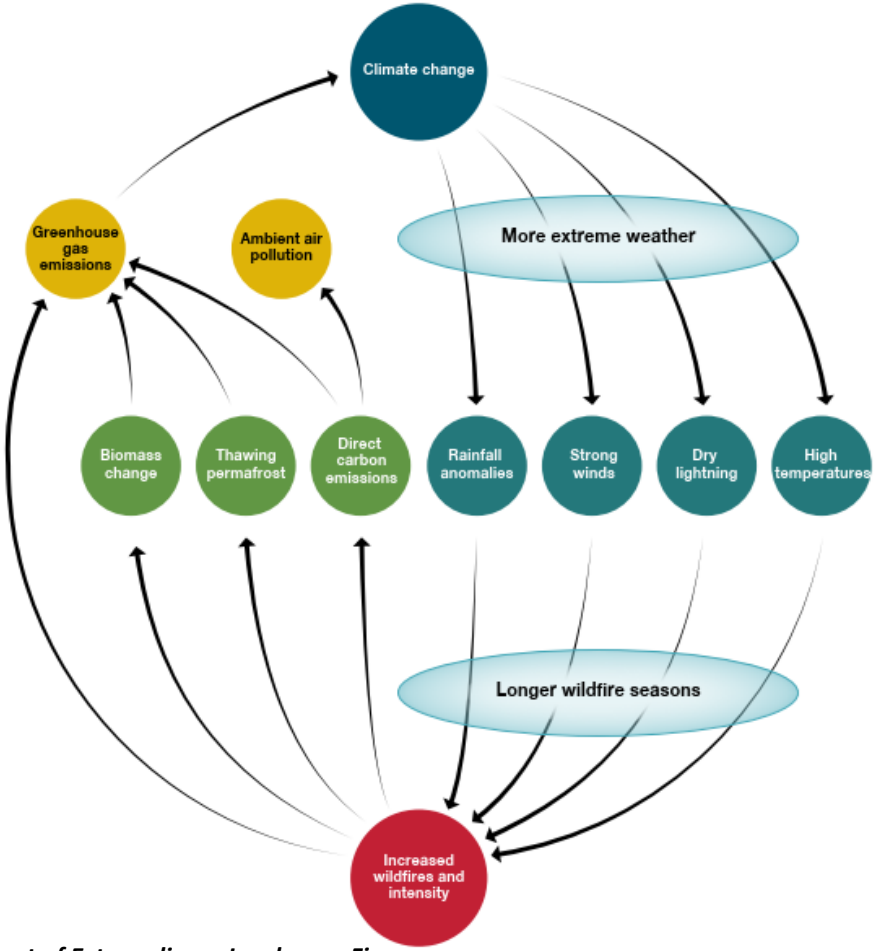
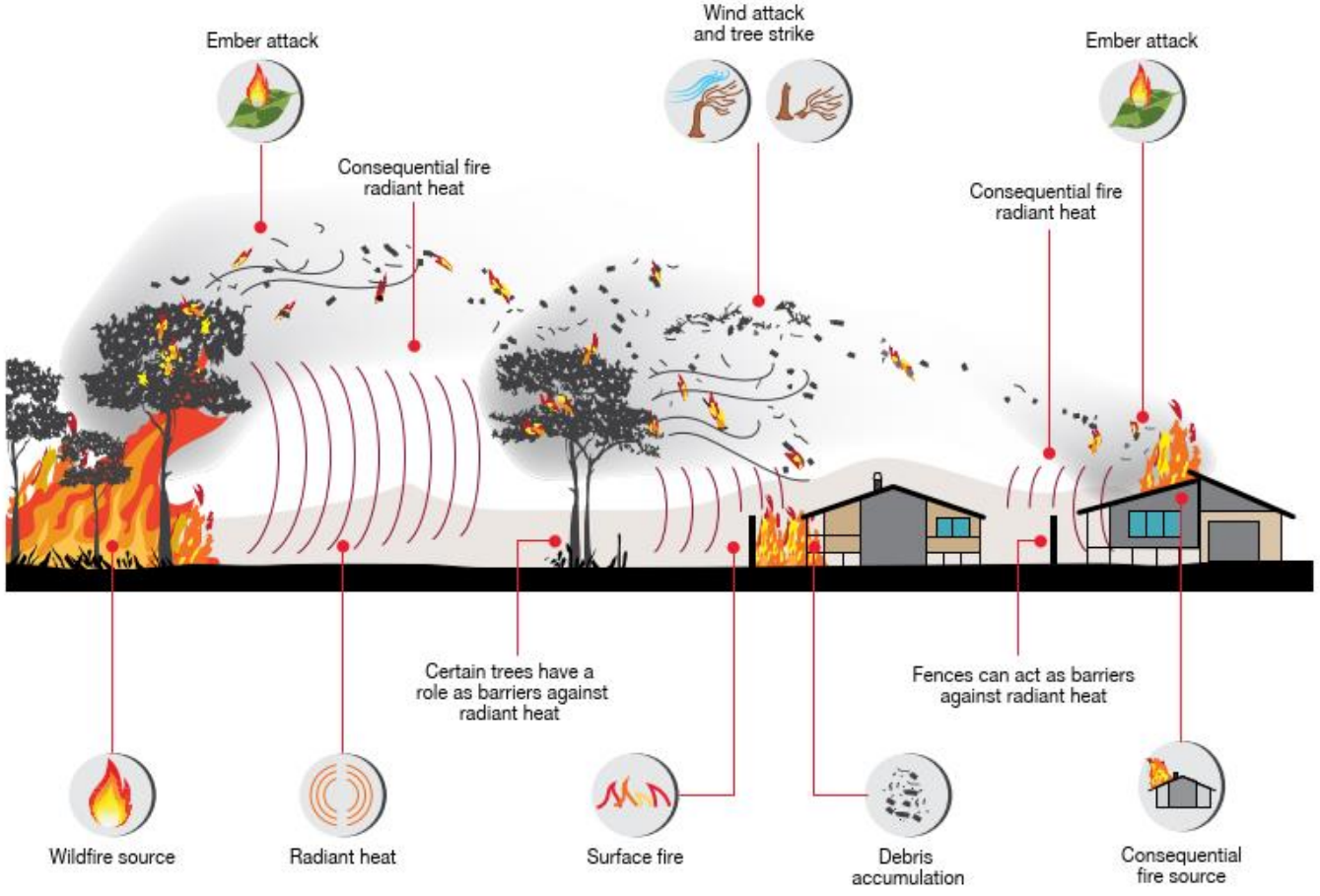
Role of Climate Change in Wildfires





UNEP (2022). ***Spreading like Wildfire – The Rising Threat of Extraordinary Landscape Fires.***

Wildfires in the Built Environment



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The Built Environment - Residential

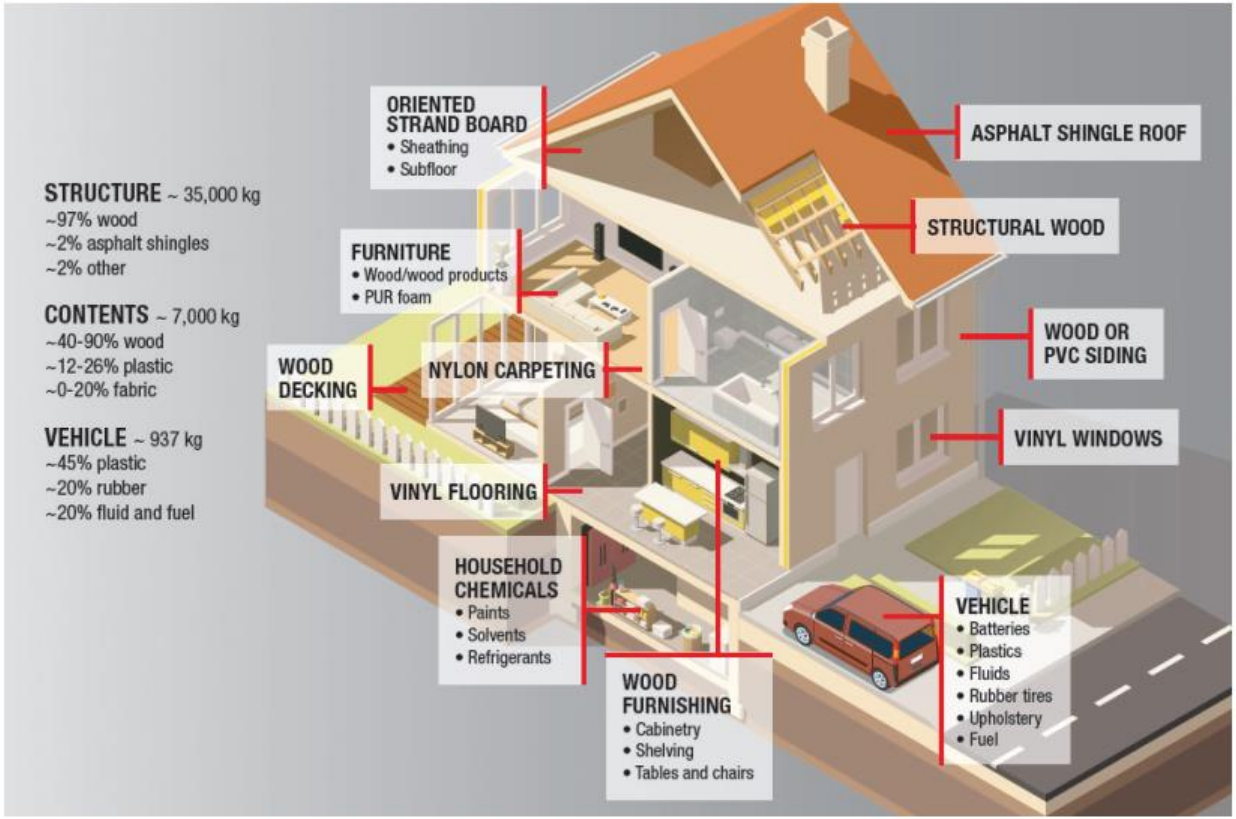

FIGURE 3-1 Examples of the types and quantities of materials that can be found in the home.

Reference: The Chemistry of Fires at the Wildland-Urban Interface (2022), National Academies Press

The Built Environment - Common "Residential" COPCs

TABLE 3-1 Materials Used in Buildings and Their Common Fire Emissions

Material	Most Commonly Released Fire Emissions
Polyurethane foam in insulation	HCN, CO, NO, NO_2, NH_3, HCl, H_3PO_4, PM, PAHs, VOCs, SVOC, TCPP, TCEP, PCDDs, PCDFs, isocyanates
Polyisocyanurate foam in insulation	HCN, CO, NO, NO_2, NH_3, HCl, H_3PO_4, PM, PAHs, VOCs, SVOC, TCPP, TCEP, PCDDs, PCDFs, isocyanates
Phenolic foam in insulation	SO_2, CO, HCl, acrolein, formaldehyde, PM, PAHs, VOCs, SVOCs, TCPP, TCEP, PCDDs, PCDFs
Extruded polystyrene in insulation	HF, HBr, CO, PM, PAHs, VOCs, SVOCs
Glass wool in insulation	HCN, CO, NO_2, HCl, isocyanates
Oriented strand board (OSB)	HCN, CO, NO_2, HCl, acrolein, formaldehyde, PM, PAHs, VOCs, SVOCs, isocyanates
Vinyl siding and/or polyvinyl chloride (PVC) windows	HCl, CO, PCDDs, PCDFs
Upholstery on furniture	HCN, CO, NO, NO_2, NH_3, HCl, H_3PO_4, PM, PAHs, VOCs, SVOC, TCPP, TCEP, PCDDs, PCDFs, isocyanates
Vinyl carpet	HCl, CO, PCDDs, PCDFs
Polyamide carpet	HCN, CO, NO, NO_2, NH_3, PM, PAHs, VOCs, SVOCs, isocyanates
Electrical wiring insulation	HCl, CO, PCDD, PCDFs
Acrylic clothing	HCN, CO, NO, NO_2, NH_3, PM, PAHs, VOCs, SVOCs, isocyanates
Residential furniture	Benzene, toluene, formaldehyde, organophosphate flame retardants

NOTES: PAH = polycyclic aromatic hydrocarbon; TCPP = tris(1-chloro-2-propyl) phosphate; TCEP = tris(2-chloroethyl) phosphate; PCDD = polychlorinated dibenzo-p-dioxin; PCDF = polychlorinated dibenzofuran.

Reference: The Chemistry of Fires at the Wildland-Urban Interface (2022), National Academies Press

- Combustion Gases (HCN, CO, NO, NO2)
- VOCs (benzene)
- Aldehydes (formaldehyde, acrolein)
- PAHs
- Particulate Matter
- SVOCs
- Dioxins/Furans

- Heavy Metals

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The Built Environment - Commercial/Industrial COPCs

- Commercial/Industrial COPCs are highly variable and dependent on activities on site.
- Consider materials stored, activities at site when fire occurred, and by products of combustion associated with fire.
- CCME Guidance for Environmental Site Characterization

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Table 4-1: Contaminants Commonly Associated with Various Activities
(adapted from Health Canada PQRA Guidance, 2007)

Note: Acromyms follow table

Industrial Facility/Operation	Potential Contaminants
Abandoned Laboratory/Chemical Facilities	Metals, cyanide, ACM, pH changes, VOCs, PAHs, PCBs, solvents, site-specific chemicals used, stored or manufactured on-site
Adhesives Manufacturing and Storage	Variable depending on type; water-based, solvent-based, epoxy resin based, natural adhesives (e.g., rubber), solvents, PHCs, isocyanate or cyanocrylates
Agricultural Operations	Pesticides, metals (as components of pesticides), microbiologicals, nitrates
Airstrips/Hangars Operations	PHCs, BTEX, PAHs, ethylene glycol, VOCs (notably degreasing solvents), metals
Antifreeze bulk storage or recycling	Glycols
Ash from Incinerators or other Thermal Facilities	Metals, pH change, PAHs, PCBs, dioxins/furans (depending on feedstock)
Asbestos Mining, Milling, Wholesale Bulk Storage or Shipping	ACM
Automotive Repair, Maintenance, Autobody Shops	Metals (notably aluminum, cadmium, chromium, lead, mercury), VOCs, PHCs, BTEX, PAHs, acetone, carbon tetrachloride, PCE and degradation products, TCE and degradation products, ethylene glycol, CFCs, pH changes
Battery Recycling, Disposal	Metals (notably arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc), pH changes
Coal Gasification Plants/Coal Tar Sites	PAHs, BTEX, cyanide, phenols, ammonia, metals (notably aluminum, chromium, iron, lead, nickel), pH changes
Drum and Barrel Recycling	Cyanide, pH changes, pesticides, PHCs, BTEX, PAHs, solvents
Dry Cleaning	PCE and degradation products, some new dry cleaners used hydrocarbon based cleaners
Dye Facilities	PAHs, benzene, toluene, metals (notably cadmium, chromium, copper, lead, mercury, nickel, zinc), anilines, amines, quinolines, pH changes
Electrical Equipment/Transformers	PCBs, PHCs (mineral oils), possibly PAH and metals
Explosives or Ammunition Manufacturing	Metals, nitrates
Electroplating	Metals (notably cadmium, chromium, copper, nickel, zinc), cyanide, TCE and degradation products, TCA, pH changes
Electronic/Computer Equipment Manufacturing	Solvents, TCE, TCA and degradation products, PHCs, metals
Fertilizer Manufacturing and Storage	Nitrate, chloride, sulphur, metals
Fire Training Areas	PHCs, PAHs, VOCs (notably, solvents), lead, MTBE, PFOS, PFOA
Fire Retardant Manufacturing	Metals (notably antimony and brominated compounds such polybrominated diphenyl ether), PFOS, PFOA
Firing Range	PAHs, metals (notably arsenic, antimony, lead), possible ordnance (see "ordnance sites"), herbicides
Foundries and Scrap Metal Smelting	Metals
Glass Manufacturing	Metals (notably arsenic, cobalt, thorium, uranium and zinc), radioactive material, PHCs, BTEX, PAHs
Ink Manufacturing	PHCs, BTEX, metals
Landfills	Metals (including iron, mercury, lead, zinc), PHCs, BTEX, PAHs, VOCs, phenols, cyanide, PCBs, PCDDs/DFs, pesticides, gases (including methane, carbon dioxide)
Machine Maintenance Shops, Metal	Metals, VOCs, TCE and degradation products
Metal Plating or Finishing	Metals, pH changes, cyanide, chlorinated solvents if used for cleaning metal
Mining, Smelting, Ore processing, Tailings	Metals, pH changes, ACM, cyanide
Mining of Coal	Metals, pH changes, sulphur, PAHs
Ordnance Sites	Metals, nitro substituted phenols and benzenes, trinitrotoluene (TNT), nitroaromatics, cyclotrimethylene trinitramine (RDX), hexahydro-1,3,5-trinitro-1,3,5-triazine, nitroglycerin, VOCs and SVOCs (including formaldehyde), toluene, herbicides, perchlorate, cyclic nitramine explosive HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine). Unexploded ordnance (UXO) may be viewed as a potential contaminant source, but not necessarily a contaminant in itself.
Paint Industry	Benzene, toluene, xylene, metals (notably cadmium, chromium, lead, mercury, zinc), herbicides/fungicides, VOCs
Pesticide Production and Use	Benzene, xylene, carbon tetrachloride, cyanide, metals (notably arsenic, cadmium, lead, mercury), CCA, VOCs, pesticides
Oil and Gas – Downstream Petroleum Facilities (service stations, tank farms, cardlots)	PHC (notably F1 and F2), BTEX, PAHs (notably naphthalene), MTBE, organic lead compounds, glycols, other additives, redox changes (possible mobilization of certain metals)
Oil and Gas – Oil Refineries	PHC (F1 to F2), BTEX, VOCs, metals
Oil and Gas - Drilling & Exploration Sites (well-heads, sumps, flare pits)	Crude oil (PHCs (F1 to F4), PAHs, BTEX, metals), produced water (salinity, sodicity, chlorides, sulphates, soluble inorganics), workover fluids (pH, salinity, methanol, glycol, brocides), chemical additives (pH, sodium, potassium, salinity, chloride, sulphates), halogenated solvents
Oil and Gas – Pipelines (transfer stations, pipeline leaks, cleanouts)	Crude oil and condensate (PHCs (F1 to F4), PAHs, BTEX, metals), waxes (F3 and F4), halogenated solvents to clear lines
Oil and Gas - Waste Oil (reprocessing, recycling or bulk storage)	PHC, VOCs, BTEX, metals
Photographic Facilities	Metals (notably chromium, lead, mercury), TCA
Plastic Manufacturing	PHCs, BTEX, styrene, isocyanites, PBDEs
Print Shops	Metals, VOCs, toluene, xylene, pH changes
Pulp and Paper Mills	Metals (notably boron, cadmium, chromium, mercury, lead, zinc, silver, titanium), VOCs, phenols, dioxins/furans, PCBs, pH changes, cyanide
Quarry Sites	Metals, VOC
Rail Yards, Maintenance and Tracks	PHCs, BTEX, PAHs, VOCs (including solvents and degreasing agents), phenols, PCBs, metals (notably arsenic, cadmium, lead, mercury)
Salt Storage	Chloride, Sodium
Salvage/Junk Yards	Metals, VOCs, ACM, cyanide, PCBs, PHCs, BTEX, PAHs
Scrap Metal	Metals, ACM, BTEX, halogenated solvents (notably TCE, TCA and degradation products), PCBs
Snow from Street Removal Dumping	Metals, chloride, sodium
Steel Manufacturing/Coke Ovens	Metals, BTEX, PAH, PHCs, phenol

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Potential Environmental Impacts from the Response Activities

- Long-term Fire Retardants
- Class A Foam Suppressants (Phos-Chek)
- Water Enhancers

- Generally, exclude Class B Foam Suppressants (e.g., PFAS-containing AFFF)

Class A Foams mostly contain inorganic salts (ammonium, phosphates, sulfates)

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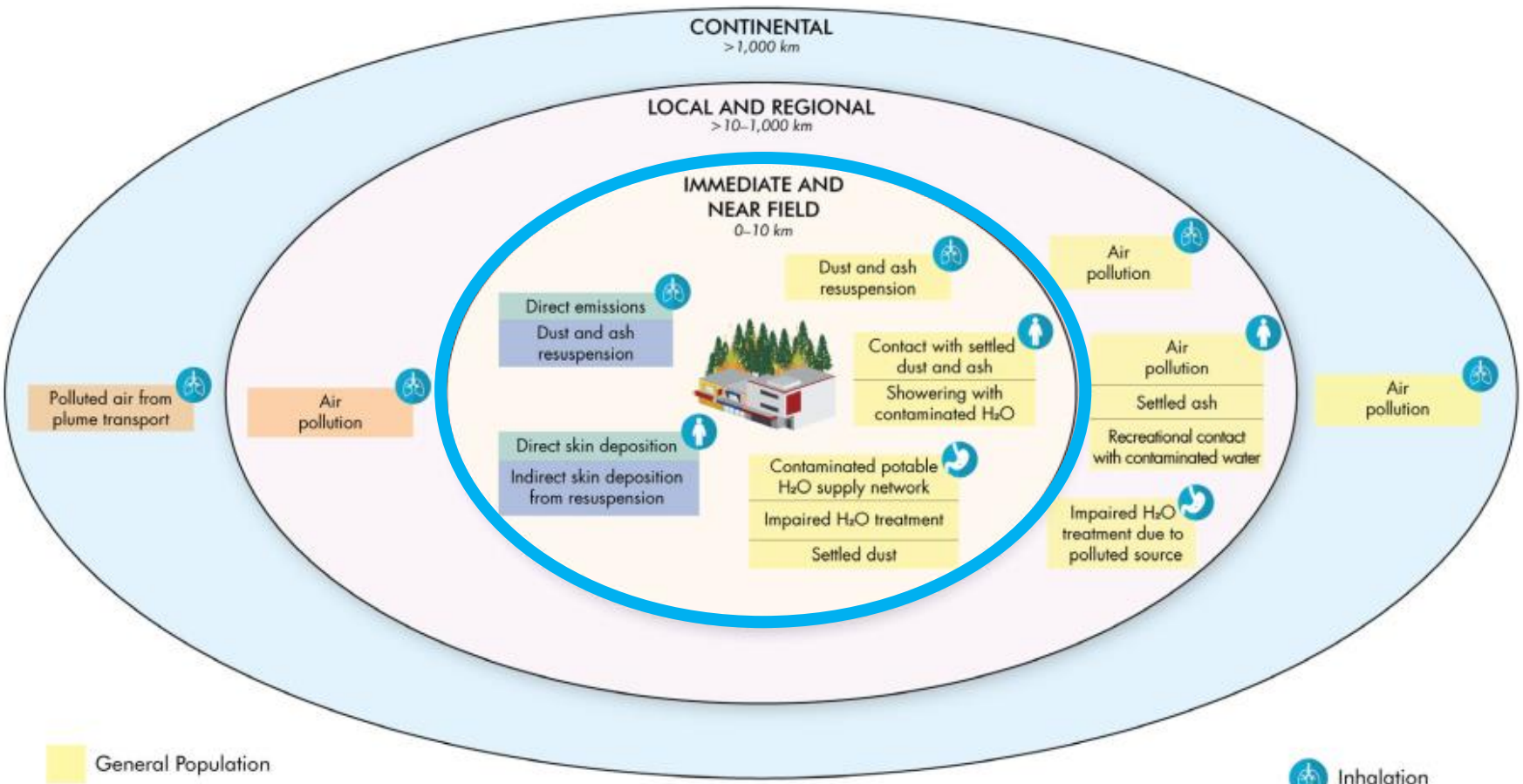
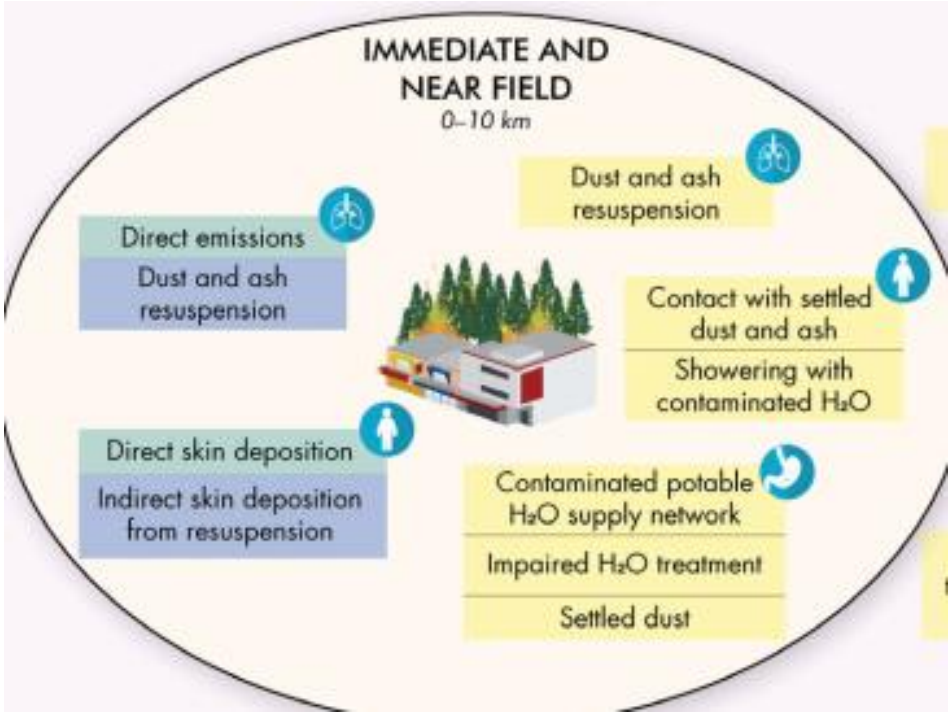


Potential Exposure Pathways

National Academies Press. ***The Chemistry of Fire at the Wildland-Urban Interface (2022).***

What are the Risks?

- **Air Quality**
  - Residual Air Quality (outdoor & indoor)
  - Resuspension of Ash, Soot, and Particulate Matter
- **Water Quality**
  - Runoff (ashes, firefighting chemicals, sediment)
  - Organic chemical and nutrients
  - Metals and organic contaminants
  - Can affect water supply
- **Soil Quality**
  - Atmospheric Deposition
  - Mobilization/Partitioning of contaminants



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Wildfire Effects on Water and Soil

- Surface Runoff (and turbidity) increases
- Water temperatures increase
- Elevated pH due to ash
- Nutrient levels increase and remain elevated for years
- Metal concentrations increase by orders of magnitude
  - Arsenic
  - Mercury is mobilized yielding elevated levels of methylmercury
- PAHs concentrations in ash and topsoil increase (after mild intensity fire)
- Impacts on fish habitat
- Potential increase in algae (eutrophication)

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Data Gaps

- Lack of detailed information on specific contamination of water or soil where fire burned an area characterized as built environment.
- Limited data exist on the potential mobilization of nutrients from the combustion of urban materials
- Limited information exists regarding direct soil and groundwater contamination following a wildland-urban interface fire.

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Wildfire Recovery/Response

Source: abcnews.go.com/US/apocalyptic-views-deadly-california-wildfires/story

Wildfire Recovery/Response generally includes two broad phases:

- **Phase 1:** Household Hazardous Waste (HHW)/Opportunistic ACM Removal, and Ash/Dust Exposure Mitigation.
- **Phase 2:** Ash and Debris Removal**.**

Wildfire Recovery - Phase 1: HHW Removal

HHW requires special handling and disposal:

- Chemicals (paints, cleaners, solvents)
- Petroleum Products
- Car/EV Batteries
- Pesticides/Herbicides
- Compressed cylinders/propane tanks
- ACM (if readily identifiable)

Source: www.registerguard.com/story/news/2020/10/30/epa-begins-hazardous-material-cleanup-after-holiday-farm-fire/6062417002/

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Wildfire Recovery - Phase 1: Stabilization

- Fire-debris and ash may include lead, arsenic, PAHs, dioxins, asbestos or other hazardous substances.
- Building ash sampling is required to demonstrate acceptability for disposal at a Class II landfill.
- Application of soil stabilizers (Soiltac®, Posi-Shell®, etc.) to the ash and debris footprints mitigates ash/soot from being released into the air, leaching into groundwater, or entering water bodies.

Source: https://www.lscenv.com/disaster-response-solutions-pg.html

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Wildfire Recovery - Phase 1: Other Human Health & Ecological Considerations

- Evaluation of drinking water systems drawing water from wildfire affected water bodies (↑ ash and sediment → turbidity, Dissolved Organic Matter)
- Protect water quality and sensitive riparian habitats in wildfire-affected watersheds.

Source: ordeq.org/EPACleanupMap

Wildfire Recovery - Phase 2: Ash and Debris Removal

Source: ordeq.org/EPACleanupMap

- Complete ACM assessment and removal.
- Remove fire-impacted metal, ash, debris, concrete (including foundations) and contaminated soil (0.1 to 0.15 m).
  - Water as a dust suppressant
  - Waste segregation/separation
- Soil Analysis: Compare soil results to cleanup goals (consider background).
- Erosion Control: Install hydromulch, straw bales, silt fencing, and/or wood chips to prevent erosion.

Wildfire Recovery - Special Considerations

- Commercial/industrial properties warrant special considerations including COPCs and infrastructure.
- Consider damage to tanks (USTs and ASTs), product piping, vent piping, etc.

(*Wildfire Guide Preparation And Recovery For Underground And Aboveground Storage Tank Systems ((EPA 510-B-21-001). September 2021*)

Source: https://www.epa.gov/ust/wildfire-guide-preparation-and-recovery-underground-and-aboveground-storage-tank-systems

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Case Study - Wildfire Recovery – Western Canada

- Wildfire destroyed 36 camp sites and 33 structures including the Visitor Centre, Stables, Youth Camp, and Operations Compound, and Maintenance Shed.
- Dillon was retained to address environmental impacts at nine sites caused by the fire and prevent further adverse effects on the Park's ecosystem.

Source: Dillon

Wildfire Recovery – Phase 1: Waste Characterization, HAZMAT, & Delineation Sampling

Source: Dillon

- Completed ACM assessment.
- Segregated burnt trailers/vacuum truck/golf carts as well as stored paint and fuel canisters.
- Sampled ash to demonstrate acceptability for disposal at a Class II landfill.
- Collected background soil samples.
- Collected soil samples that, along with known and perceived hazardous debris, were used to delineate the extents of the contamination → High wind conditions resulted in continually distributing debris across the landscape.

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Wildfire Recovery – Phase 1: Challenges

Source: Parks Canada

- Snow, up to 1.2 metres deep, curtailed the construction season and made characterization of the extent of fire-impacted metal, ash, and debris difficult.

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Wildfire Recovery – Phase 2: Ash and Debris Removal

Source: Dillon

- Mandatory site meeting during the tender period established the extent of the project sites based on observed conditions.
- Removed fire-impacted metal, ash, debris, asbestos, concrete (existing building foundations) and contaminated soil (from 0.1 m to 0.5 m) .
- Metal debris (e.g., vehicle trailers, burned vacuum truck, golf carts) were recycled.
- Confirmatory samples were collected following excavation demonstrating that ash and wildfire-impacted soil had been effectively removed and disposed.

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Questions/Discussion

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