ICS 921
The NIOSH Hierarchy of Controls for Exposure Reduction

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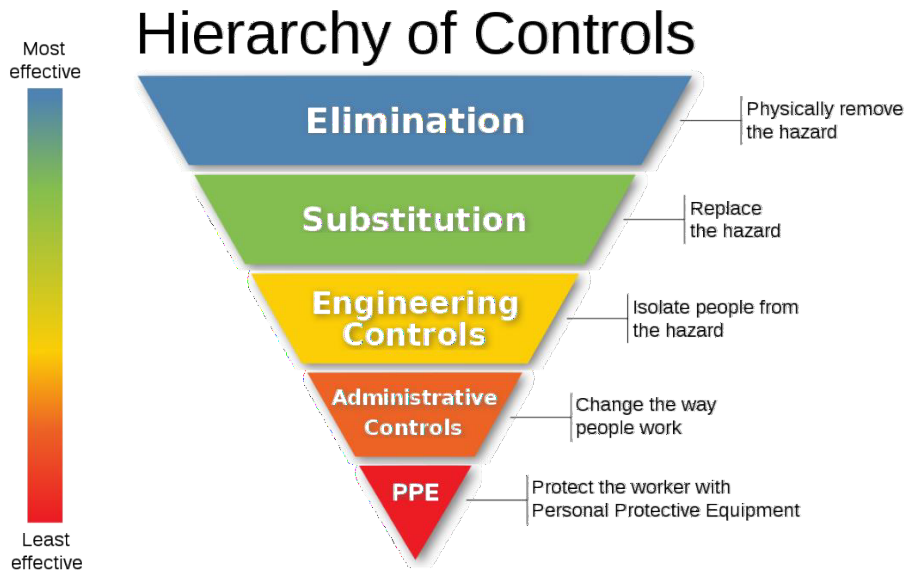
for
Exposure Reduction

The International Agency for Research on Cancer classifies occupational exposure as a firefighter as a Group 1 known human carcinogen. This is because of firefighters' heavy burden of exposure to multiple carcinogenic agents such as combustion products, diesel exhaust, and shift work with sleep disruption. In order to reduce cancer risk for firefighters, exposure to carcinogenic agents must be reduced to the greatest extent possible while public safety duties remain the highest priority.

The NIOSH Hierarchy of Controls can be applied by members of the fire service of all ranks from chief fire officers to new recruits in order to reduce occupational exposures. The Hierarchy of Controls is **not a checklist**, it is an approach designed to systematically identify actions, in order of greatest effectiveness, that can be taken to reduce exposure in any setting, whether it be daily firehouse life or an emergency incident. Applications of the Hierarchy of Controls do not have to be costly or logistically difficult to implement and can range from the implementation of department wide policies to a firefighter simply stepping up wind from smoke when practical.



As part of its 2023 Plan of Work, the FIRESCOPE Cancer Prevention Subcommittee is developing educational material designed to teach the Hierarchy of Controls as an approach that can be applied to settings including but not limited to: policy development, daily firehouse life, and fire ground strategy/tactics while always placing public safety duties first. Included below is an introductory outline of the actions (Elimination, Substitution, Engineering Controls, Administrative Controls, PPE) that comprise the Hierarchy of Controls. Additional updates detailing each action will follow in the future.

1. Elimination
The most effective way to control an exposure is to eliminate the source of the exposure altogether. A simple example could be parking a fire apparatus on the front apron for part of the day, when feasible, in order to eliminate diesel exhaust exposures inside the fire station.

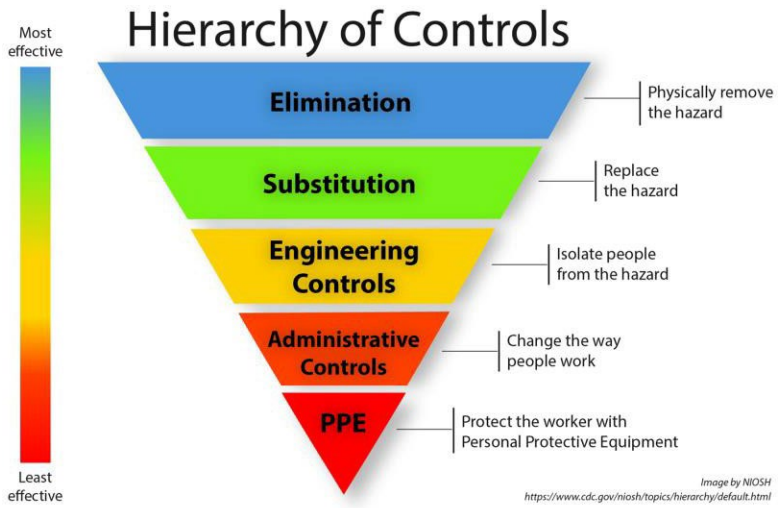
2. Substitution
When a source of exposure cannot be eliminated altogether, the second most effective approach is to substitute something else in its place that is not hazardous or less hazardous. An effective example supported by toxicological research is replacing the fuel packages in training fires with materials that result in less hazardous exposures.

3. Engineering Controls
When a source of exposure cannot be eliminated or substituted for an alternative, efforts can be made to isolate firefighters from the exposure use engineering controls to keep the hazard from reaching firefighters. Fire station diesel exhaust removal systems are a well-known example of an engineering control. Stepping up wind from smoke when practical is another example that is simple to implement by firefighters of any rank.

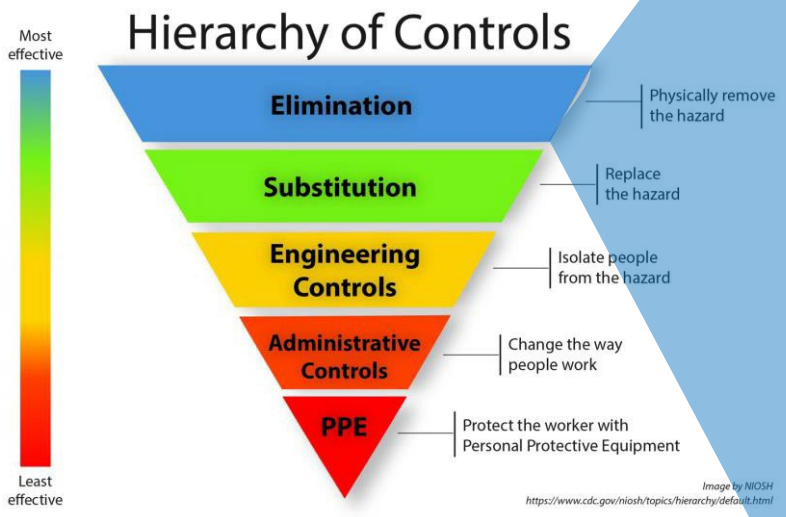
4. Administrative Controls
When engineering controls cannot be implemented to isolate firefighters from a source of exposure, changing the way they work via administrative controls, while prioritizing public safety duties, can reduce the burden of exposure. For example, after knock down at a structure fire, crews can roll hose, refuel saws, and prepare to go back in service while the structure is adequately ventilated and before beginning overhaul so that overhaul is conducted in a less hazardous environment. This approach does not change any job task at a structure fire, only the order in which those tasks are carried out.

5. Personal Protective Equipment
The use of personal protective equipment (PPE) is considered the least effective way to control exposure as compared to the actions above. Many chemical carcinogens are absorbed through the skin, and full structural firefighting PPE does not completely halt this route of exposure. However, the **correct use of full structural firefighting PPE and self-contained breathing apparatus is a firefighter's best/last line of defense to reduce exposure** when the actions described above cannot be implemented effectively.

NIOSH Hierarchy of Controls for Exposure Reduction



- Not a checklist
- An approach to systematically identify actions to reduce carcinogen exposure
  - Listed in order of greatest effectiveness
  - Can be applied in any setting
    - Fire ground
    - Fire training
    - Fire station
    - Diet
    - Home life
- Does not have to be costly or logistically difficult
- Can range from:
  - Department wide policies
  - An individual firefighter stepping up wind from smoke



ELIMINATION

PHYSICALLY REMOVE THE HAZARD

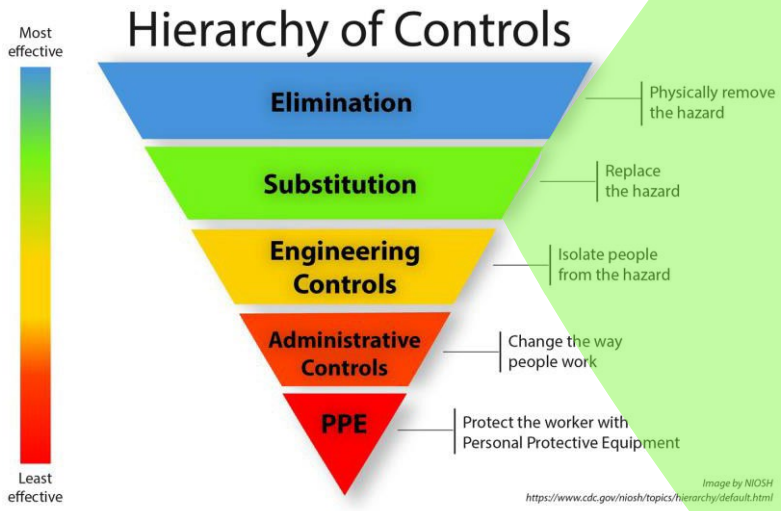
Ventilation During Structural Firefighting Operations & Overhaul: Products of combustion contain a myriad of chemical carcinogens to which firefighters are exposed via inhalation and transdermal absorption. Effective and coordinated ventilation during firefighting operations as well as prior to and during overhaul physically removes products of combustion from the interior of the structure, thus eliminating exposure to chemical carcinogens that are removed. Note however that this approach does not eliminate all contaminants from the fire-ground, and full structural firefighting PPE and SCBA should be used at all times to further reduce exposure.

Post Fire Incident Shower: Use of full structural firefighting PPE and SCBA reduces but does not eliminate chemical carcinogens that are deposited on the skin. The longer these chemical carcinogens remain on the skin of firefighters, the greater the magnitude of transdermal absorption. Showering as soon as possible after a fire incident is the most effective way to remove chemical carcinogens from the skin. Implementing post fire incident PPE contamination reduction and cleaning policies is an effective way of reducing secondary exposures from contaminated equipment, but emphasis must be placed on firefighters showering.

Diesel Exhaust: Diesel exhaust is classified as a Group 1 known human carcinogen by the International Agency for Research on Cancer (IARC), and exposure by inhalation is pervasive in the fire service. Diesel exhaust systems in fire stations are an example of an engineering control that can reduce exposure, but are not as effective as shutting down apparatus to eliminate diesel exhaust altogether (when practical and not interfering with emergency incident priorities). Examples of this approach can include shutting down apparatus: during EMS calls when diesel exhaust will impact the work area, when parked in incident staging for extended periods, or when apparatus are not being utilized during an incident. Parking apparatus on the front apron of the station for even a small part of the day, when feasible, is an effective way of eliminating diesel exhaust exposures inside the fire station.

Smokeless Tobacco: Smokeless tobacco is classified as a Group 1 known human carcinogen by IARC and is linked to cancers of the mouth, tongue, cheek, esophagus, and pancreas. Despite many fire departments having policies that prohibit the use of smokeless tobacco, its use remains rampant in the fire service. Elimination of smokeless tobacco exposure can be achieved by firefighters making the individual lifestyle choice to halt its use and fire departments can encourage their members to halt its use by making widely known that its use causes cancer.

Shift Work w/Circadian Sleep Disruption: A recent report (1) by the U.S. National Toxicology Program (NTP) concluded with “high confidence” that persistent night shift work that disrupts circadian sleep can cause cancer and IARC classifies it as a probable human carcinogen. Public safety duties and nationwide recruitment and retention challenges make elimination of on duty sleep disruption difficult to accomplish, however, efforts to address “sleep hygiene” and reduce sleep disruption to the greatest extent possible via staffing policies or other approaches are a crucial component of firefighter cancer prevention and wellness.



SUBSTITUTION

REPLACE THE HAZARD

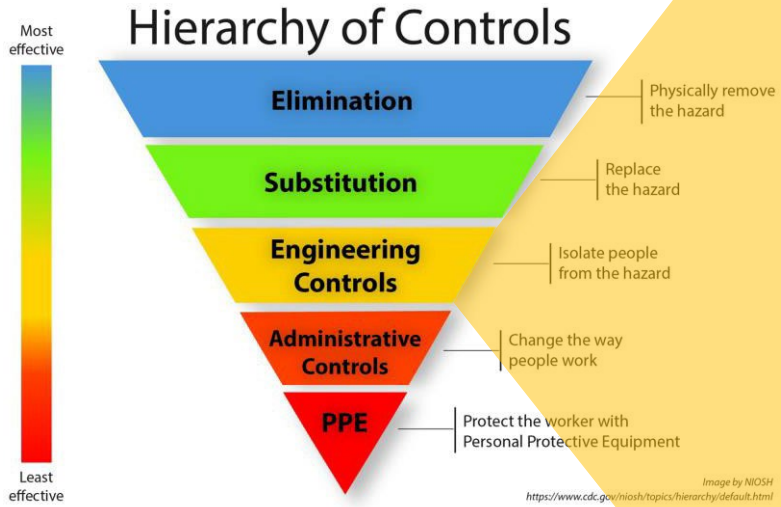
Diet - Processed Meat: The International Agency for Research on Cancer (IARC) classifies the consumption of processed meat as a Group 1 known human carcinogen [1]. Processed meat refers to any meat that has been treated by industrial processes such as: salting, curing, fermentation, smoking, or any other process that enhances flavor or extends preservation. Examples include but are not limited to bacon, sausages, canned corned beef, pepperoni, and dried/salted meats [1]. Note that industrial processing is distinct from home preparation and a comprehensive review of this topic can be found in Reference [1] below. Dietary substitutions that replace processed meats with unprocessed meats are an easy and effective way for firefighters to reduce cancer risk and improve overall health and fitness.

[1] https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono114.pdf Accessed on Nov 27, 2023

Cleaning and Disinfecting Products: Many cleaning and disinfecting products contain hazardous chemicals, some of which are known carcinogens such as ethylene oxide and formaldehyde. Maintaining a high standard of cleanliness and disinfecting EMS equipment are essential duties in the fire service, but the use of cleaning and disinfecting products should be limited to their intended applications with the use of appropriate PPE. Substituting mild soaps, detergents, and even simple hot water when possible can reduce firefighters' exposures to hazardous chemicals.

Live Fire Training Fuel Packages: Published research examining biomarkers of exposure to carcinogenic products of combustion in firefighters participating in live fire training has demonstrated that the use of engineered wood products bonded with synthetic resins such as OSB and plywood resulted in markedly higher exposure to carcinogenic polycyclic aromatic hydrocarbons (PAHs) and benzene as compared to propane or untreated lumber such as spruce and pine which resulted in lower exposures [2,3]. Leading fire service cancer researchers have recommended against the use of engineered wood products bonded with synthetic resins in training fires to reduce firefighters' cancer risk [2,4,5]. Training is an essential component of the fire service that must be prioritized, and live fire training objectives can be met while reducing carcinogenic exposures by substituting the use of engineered wood products bonded with synthetic resins in favor of less hazardous alternatives.

[2] Laitinen, Juha, et al. "Fire fighting trainers' exposure to carcinogenic agents in smoke diving simulators." *Toxicology letters* 192.1 (2010): 61-65.
[3] Fent, Kenneth W., et al. "Firefighters' and instructors' absorption of PAHs and benzene during training exercises." *International journal of hygiene and environmental health* 222.7 (2019): 991-1000.
[4] https://www.ffccs.org/component/edocman/live-fire-training-instructors/download?Itemid=0 Accessed on Nov 27, 2023.
[5] Fent, Kenneth W., et al. "Understanding airborne contaminants produced by different fuel packages during training fires." Journal of occupational and environmental hygiene (2019).



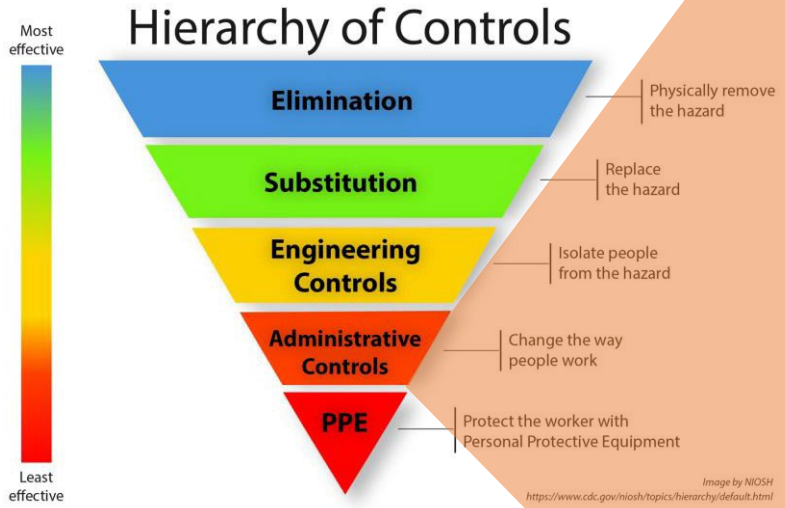
Engineering Controls
ISOLATE PEOPLE FROM THE HAZARD

Fire Station Diesel/Automotive Exhaust Removal Systems: The International Agency for Research on Cancer (IARC) classifies diesel exhaust [1] and other contaminants from automotive exhaust as Group 1 known human carcinogens. The apparatus garage and living areas in a fire station can become heavily contaminated when diesel and other automotive exhaust is allowed to flow freely. Properly installed, maintained, and utilized diesel/automotive exhaust removal systems can be effective at isolating firefighters from exposure to these emissions. These systems can also be effective at preventing contamination of equipment and surfaces that may result in secondary exposures. Properly installed/maintained weather stripping on doors and self closing doors that lead into/out of the apparatus garage are essential parts of a complete set of engineering controls that can isolate firefighters from exposure to diesel/automotive exhaust.
[1] https://www.iarc.who.int/wp-content/uploads/2018/07/pr213_E.pdf

Fire Apparatus Environmental Controls: Effective use of environmental controls on fire apparatus can isolate firefighters from sources of exposure and prevent contamination of the interior of the fire apparatus. Application of fire apparatus environmental controls can be as simple as manually rolling up windows en route to a fire incident and can range in complexity to automated systems that roll up windows when the apparatus is placed in pump. Effective cab filtration systems, recirculating air, and properly installed/maintained weather stripping are also key components of fire apparatus environmental controls that can isolate firefighters from sources of exposure.

Fire Station Design & Modifications (Hot/Warm/Cold Zones): When new fire stations are designed, or existing stations are modified, exposures resulting from contaminated PPE and equipment can be minimized by specifying hot/warm/cold zones in the station. This approach is meant to minimize inadvertent migration of contaminated materials within the station. Hot zones are those in which contaminated PPE and equipment should be handled/stored and an example may include the outside of the station. Warm zones are those in which contamination reduction activities take place and examples may include an extractor/laundry room or an equipment workroom where tools are cleaned. Appropriate PPE such as respiratory protection, latex/nitrile gloves, eye protection, and coveralls should be utilized by members working with contaminated PPE and equipment in hot and warm zones. Cold zones are those into which no contaminated PPE or equipment should enter such as living, sleep, kitchen, and office spaces.

Firefighting PPE Isolation: Firefighting PPE is a source of secondary exposure to multiple carcinogens such as products of combustion and per/poly-fluoro alkyl substances (PFAS). Examples of engineering controls that can isolate firefighters from contaminated PPE and limit exposure include: PPE storage/isolation bags utilized inside the apparatus cab, designated PPE/SCBA compartments on apparatus, and dedicated PPE storage rooms in fire stations.



Administrative Controls

CHANGE THE WAY PEOPLE WORK

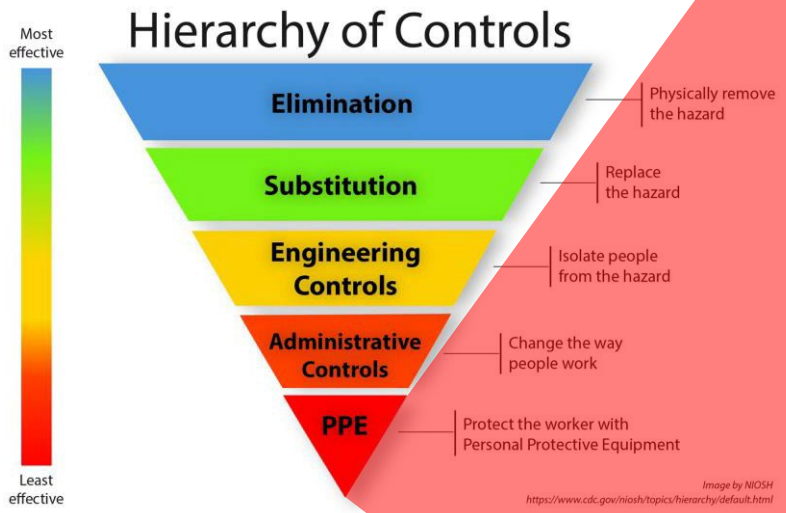
Pause Prior to Overhaul and Get Fire Ready: Overhaul is often initiated soon after knock down at structure fires, resulting in firefighters being exposed to carcinogenic products of combustion as fuels continue to smolder [1]. Although use of SCBA during overhaul is effective at preventing exposures via inhalation and should always be used, carcinogens such as polycyclic aromatic hydrocarbons (PAHs) in smoke and soot can break through structural firefighting PPE and are absorbed through the skin. Exposures during overhaul can be reduced by allowing smoldering fuels to cool and by adequately ventilating the structure prior to starting overhaul. During this pause, units assigned to the incident can prepare to go back in service by changing air bottles, reloading hose, refueling power tools, etc. This approach can reduce exposure during overhaul by merely changing the order in which tasks are done at a fire incident as opposed to changing how tasks are done at a fire incident.

[1] Bolstad-Johnson, Dawn M., et al. "Characterization of firefighter exposures during fire overhaul." *AIHAJ-American Industrial Hygiene Association* 61.5 (2000): 636-641.

Limit Duration of Exposure: Firefighters are exposed to a myriad of carcinogenic agents in the line of duty, ranging from products of combustion to shift work with sleep disruption, and many of these exposures are difficult to prevent while providing for public safety duties. Where carcinogenic exposures are unavoidable, limiting the duration of the exposure may reduce the magnitude of the exposure. This approach can be applied to many occupational exposures experienced by firefighters. During live fire training, covering training objectives in ~20 minutes rather than 30+ minutes where possible reduces the amount of time that firefighters are exposed to products of combustion while still allowing for effective training. During extensive overhaul operations, rotating crews reduces the amount of time that firefighters are exposed to smoldering products of combustion and soot. On shift work with sleep disruption, minimizing the number of consecutive days worked to the greatest extent possible reduces sleep disruption while on duty.

Post Fire Incident Contamination Reduction (Decon) & Shower Within an Hour: Firefighters are exposed to many carcinogens that are absorbed through the skin despite the use of full PPE and SCBA, and the process of transdermal absorption of carcinogens deposited on the skin does not stop until these carcinogens are removed. The use of simple baby wipes is an effective initial step to remove carcinogens from the skin that must be followed by a shower as soon as possible upon being released from a fire incident [2].

[2] Burgess, Jefferey L., et al. "Evaluation of interventions to reduce firefighter exposures." *Journal of occupational and environmental medicine* 62.4 (2020): 279-288.



PPE

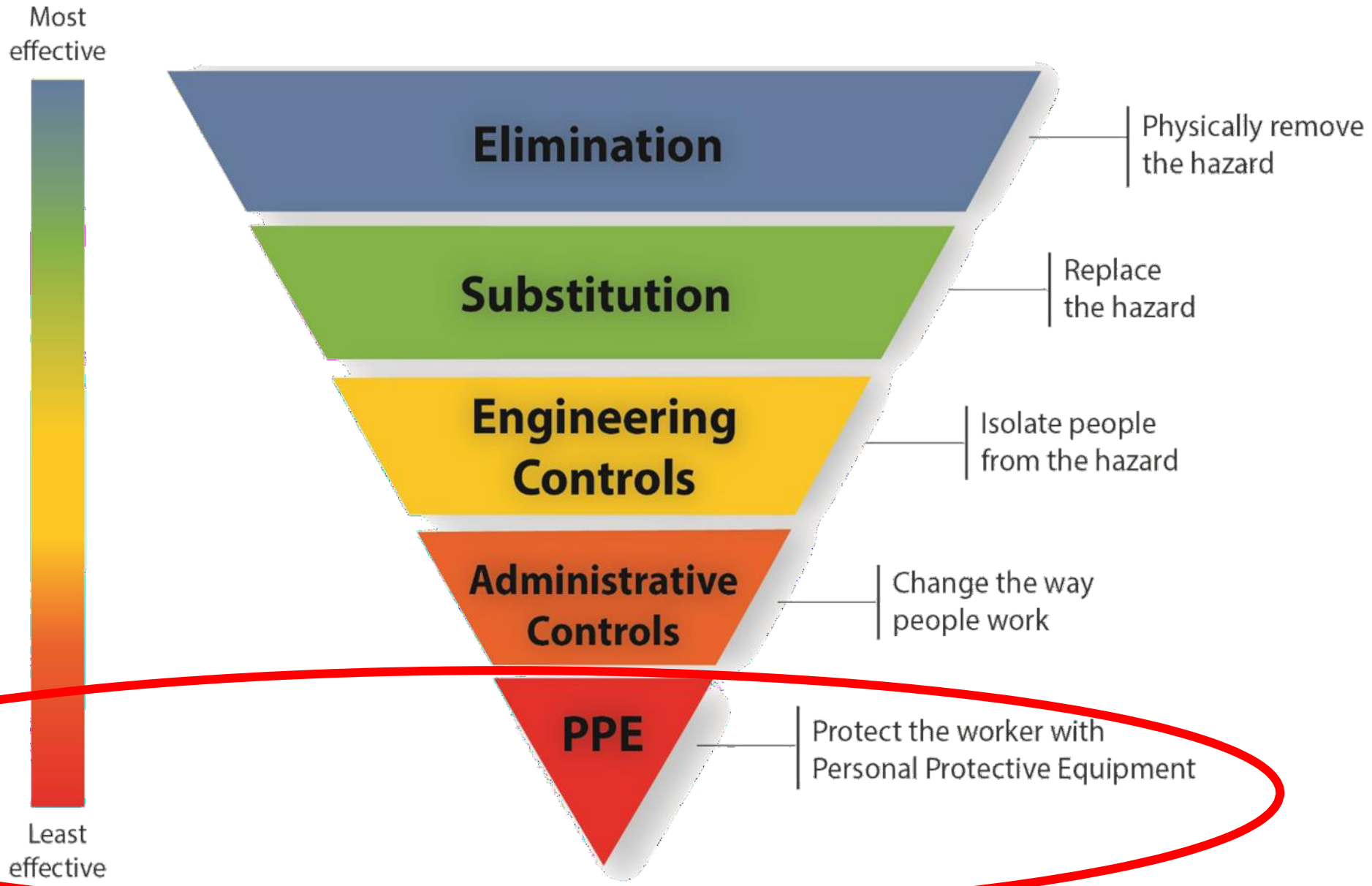
PROTECT THE WORKER WITH PERSONAL PROTECTIVE EQUIPMENT

SCBA During all Phases of Firefighting Including Overhaul: Firefighters are exposed to multiple carcinogens on the fire ground that pose an inhalation hazard, including but not limited to: polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and particulate matter. Use of a self contained breathing apparatus (SCBA) anytime there are products of combustion present is the most effective way to prevent these exposures. Note that this includes all types of fires, ranging from outdoor dumpster fires to large industrial fires.

Structural Firefighting PPE: Firefighters are also exposed to multiple carcinogens on the fire ground that pose a transdermal absorption hazard. Although structural firefighting garments are not impermeable to carcinogens, all components of a structural firefighting ensemble, including helmet, hood, jacket, gloves, pants, and boots must be worn correctly to reduce carcinogens being deposited on the skin.

Impermeable Gloves, Respiratory, and Eye Protection During Contamination Reduction: PPE and other equipment contaminated with products of combustion poses an exposure hazard to firefighters who handle the equipment. Firefighters handling such equipment should utilize impermeable gloves, respiratory, and eye protection to minimize exposure from contaminated equipment

Limitations of Firefighter PPE



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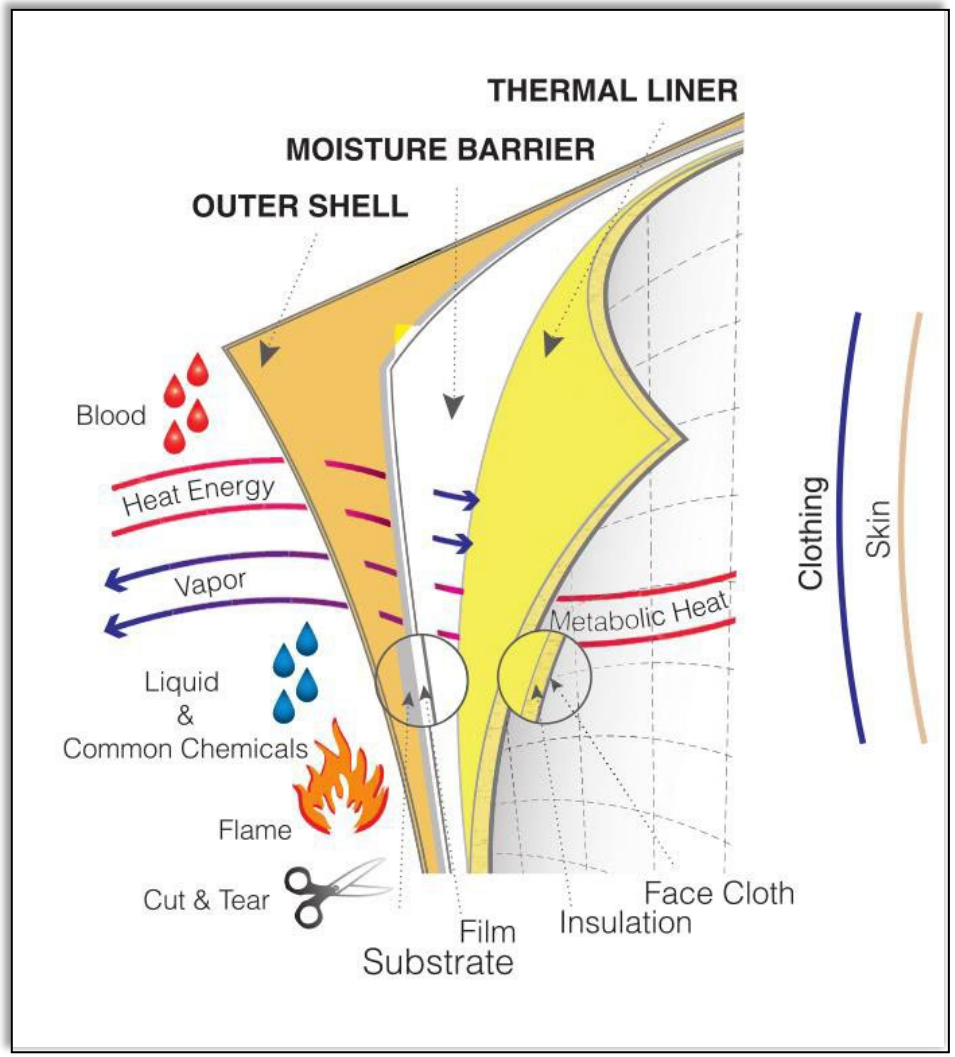
Limitations of Firefighter PPE

LEVEL A

- Totally encapsulating chemical & vapor protective suit
- **Must** be worn:
  - When working in IDLH environments
  - When working with substances that can be **absorbed by the skin**
- ***CAN NOT BE WORN BY FIREFIGHTERS***

Limitations of Firefighter PPE



Three layer ensemble of textiles (fabrics) with open interfaces

Limitations of Firefighter PPE

Interfaces result in limited protection against chemical carcinogens on the fire-ground, even with particulate blocking skirts

- Hood / mask
- Coat / hood
- Coat / gloves
- Coat / pants
- Pants / boots