



PELASTUSOPISTO
EMERGENCY SERVICES ACADEMY FINLAND

Firefighters' chemical exposure and heat stress in wildland firefighting

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Firefighters' firefighting tools and personal protective equipment in wildland fires

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0. Outline of the presentation

1. Research settings

2. Methods

3. Results

4. Conclusions



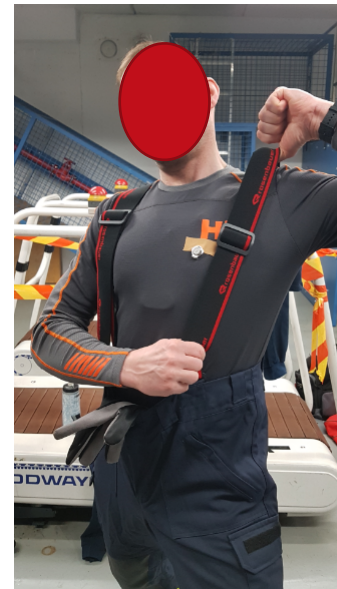
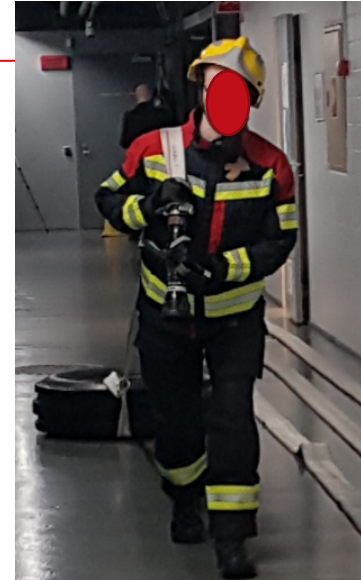
Photo: Juha Laitinen



1. Research settings

To test different fire fighting gears effect on firefighters' heat stress in the laboratory conditions

- Four firefighters tested four different garments in four one-hour wildland fire simulations (walking and carrying hoses on easy and on difficult terrains, pulling and reeling of the hoses and carrying hose reels)
- Tested garments were garment (Viking) designed for structural fires and three garments (S-GARD, Rosenbauer, and Texport) designed for wildland fires
- Firefighters used long sleeved and legged underwear, light helmet, gloves and combat boots





1. Research settings

Inhalation exposure measurements in forestry management burnings (WP2)

- ❑ In tests we simulated work tasks in wildland fires (inquiry, extinguishing with hand-held tool, back sprayer and hose)

- ❑ Duration of the four tests was about 4 hours

- ❑ Firefighters (n=4) had similar PPEs as in laboratory tests **with few exceptions:**
 - All firefighters used fan-assisted respirators equipped with A2B2E2K2-P3 – combination filter, and they carried a carbon monoxide detectors.
 - Firefighter who used Viking garment, had only shorts and t-shirt without jacket.

fan-assisted respirators equipped with combination filter

CO-detector



Photo: Juha Laitinen



1. Research settings

Firefighters heat stress, total exposure and dermal exposure was followed on the wildland fire training track (WP3).

- ❑ Improved protection was compared to traditional way to do firefighting in wildland fires in Finland
- ❑ Eight firefighters worked in pairs, and they tested both protection settings during two different test days
- ❑ Duration of the tests was 2 hours (inquiry, hose carrying in racks, hose pulling, extinguishing with hand-held tool and back sprayer and reeling of the hose)
 - Improved protection (garment designed for forest fires, long-sleeved and legged underwear, and respirator)
 - Traditional protection (garment designed for structural fires, shorts, and t-shirt, without respirator)



Photo: Juha Laitinen



2. Methods for measurements of heat stress

❑ **Skin temperature:** With five temperature sensors from back, chest, upper arm, upper and lower legs.

❑ **Relative humidity** was also measured from the surface of the shirt

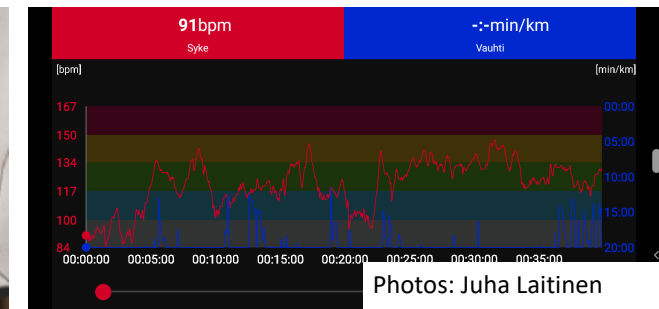
❑ **Core temperature:** With swallowable temperature capsule, which allowed online core temperature measurements

❑ **Sweating:** Firefighters' weight and the weight of their clothing were recorded before and after the tests. The amount of liquid drunk during test, was also recorded

❑ **Heart rate:** Firefighters' heart rate was recorded



<https://www.medgadget.com/2017/03/bodycap-e-celsius-electronic-pill-core-body-temperature-monitoring.html>





2. Methods: Chemical exposure measurement methods

☐ Inhalation exposure

➤ Active and passive samplers, direct reading instruments: Air samples were taken from firefighters' breathing zone outside of the fan assisted respirator (Carbon monoxide, aldehydes, inhalable dust, 35 elements, cesium 137 and VOCs).



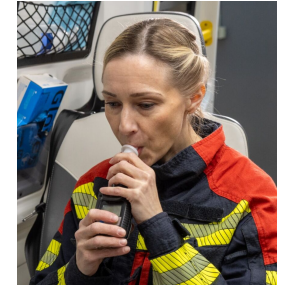
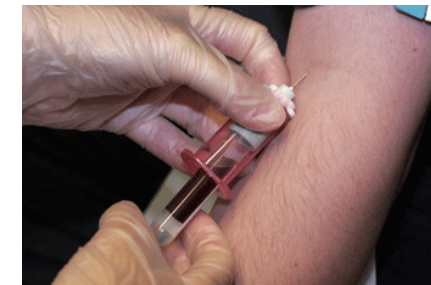
☐ Actual dermal exposure

➤ Whole body dermal exposure to PAHs: from the skin under firefighting garment (neck, chest, back, upper and lower legs)



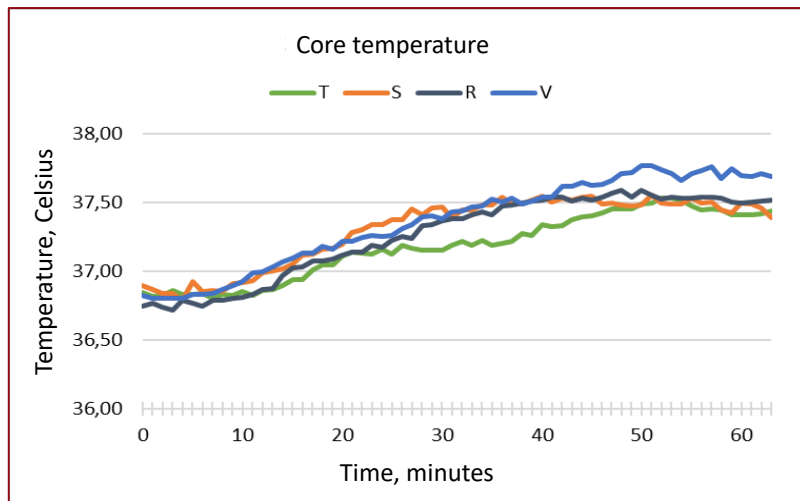
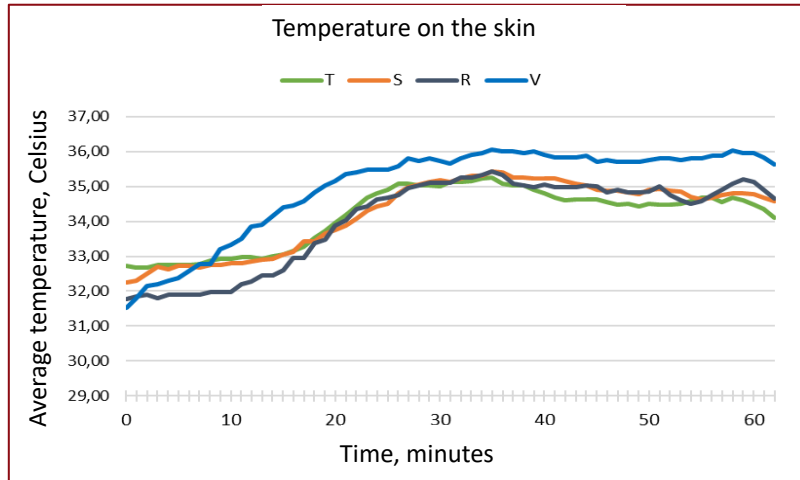
☐ Total exposure

- Urinary: 2-Naphthol, 1-pyrenol and S-phenylmercapturic acid
- Blood: Carboxyhemoglobin
- Exhaled air: Carbon monoxide

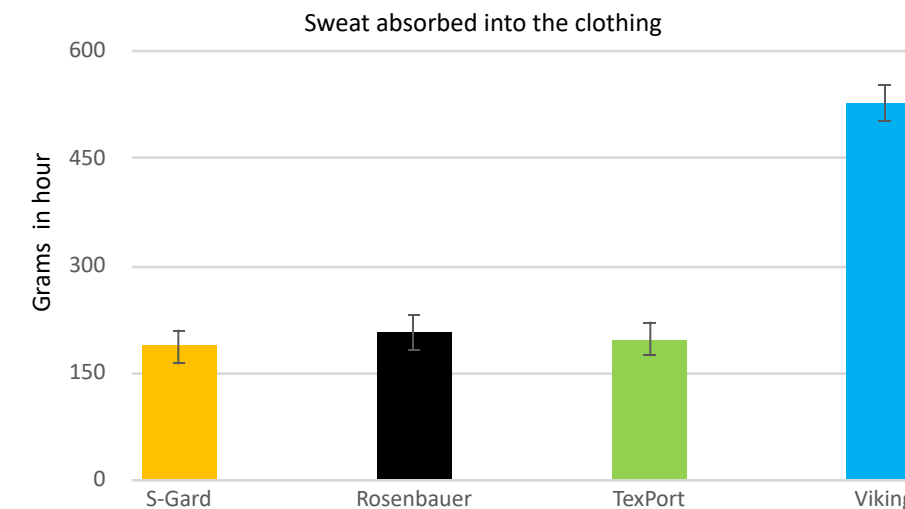




3. Results: The effect of firefighting gears on FF's heat stress



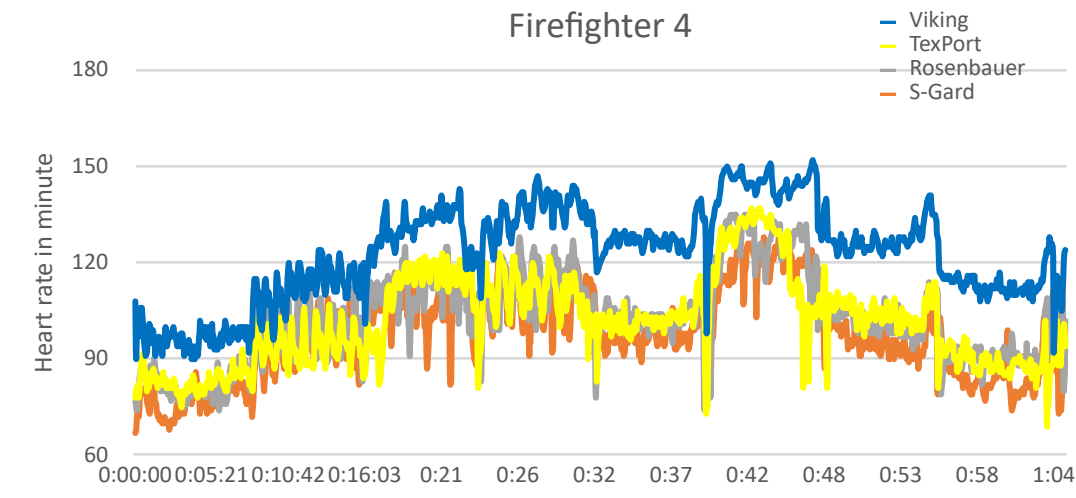
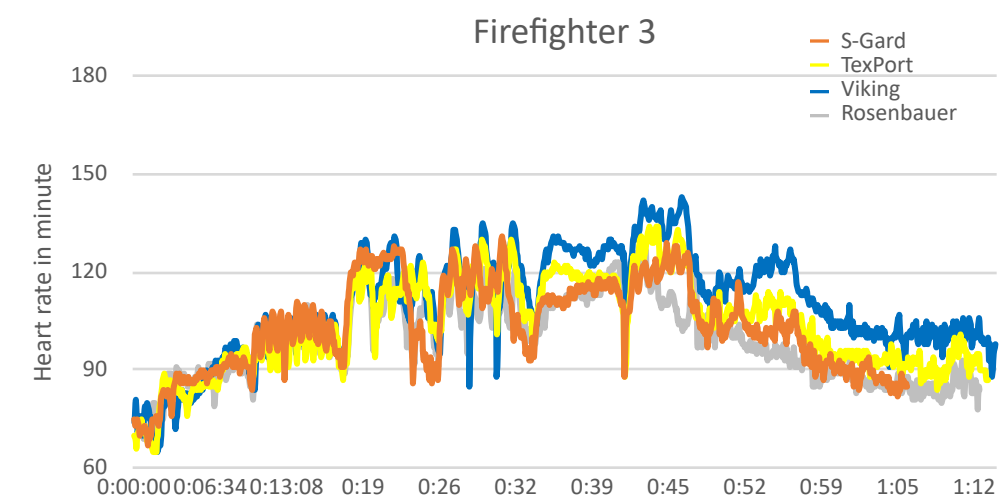
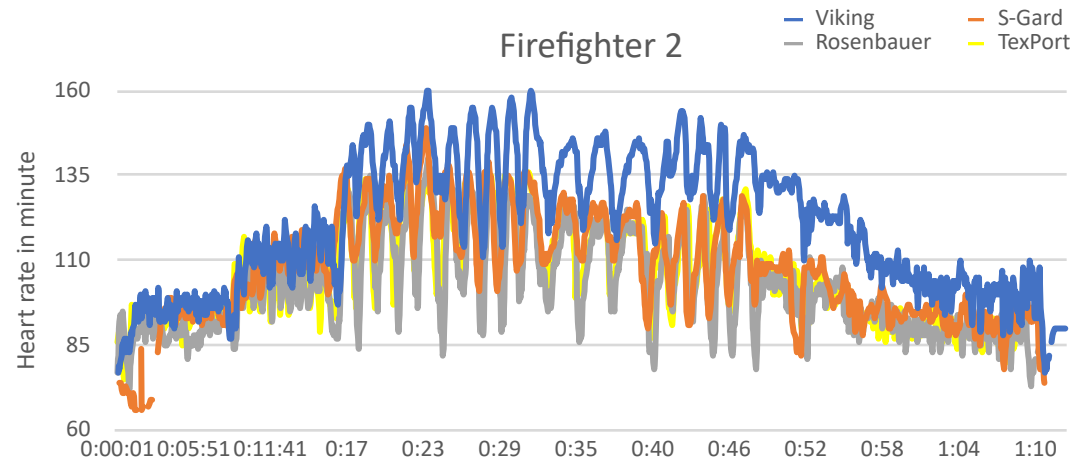
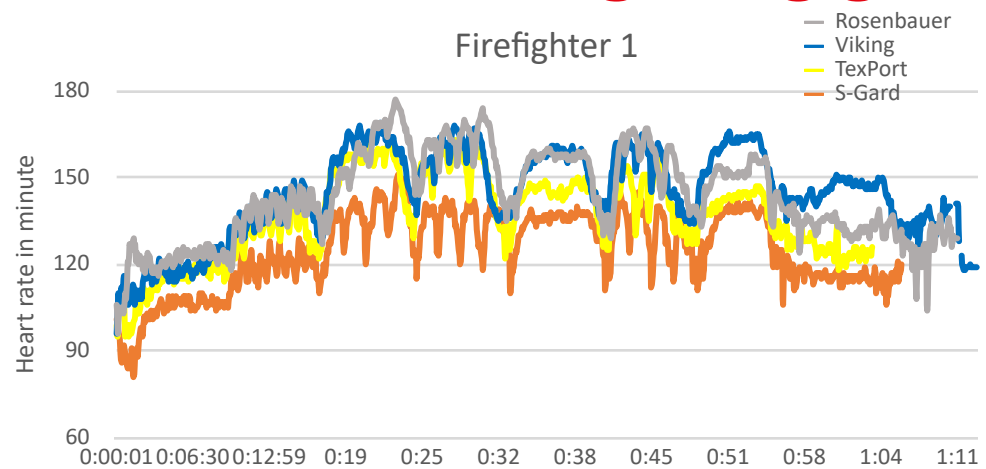
The results of garments designed for forest fires were 73 % of the results for garment designed for structural fires



The results of garments designed for forest fires were 39 % of results for garment designed for structural fires

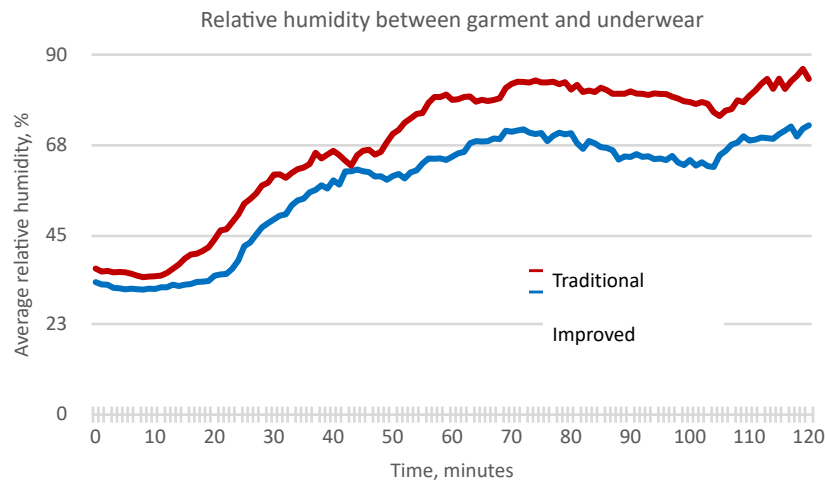
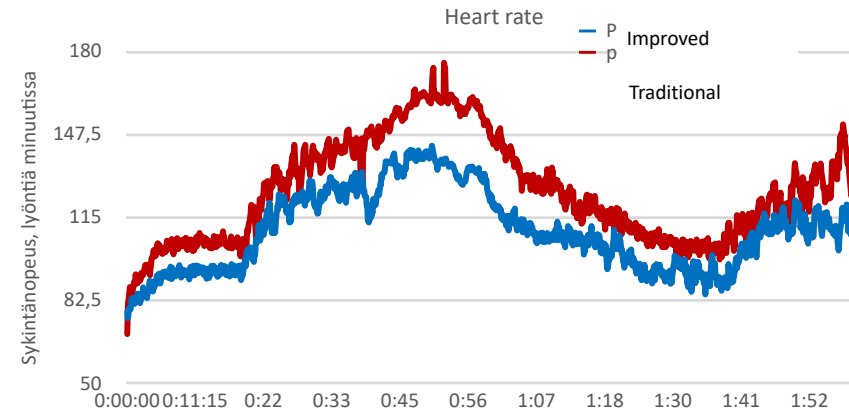
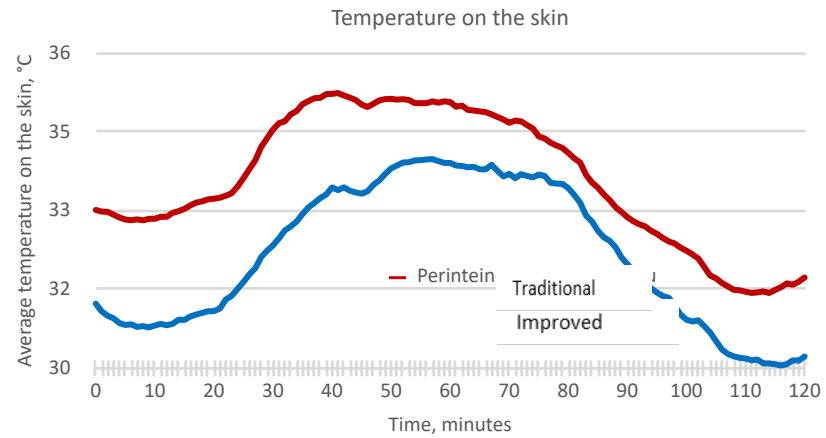


3. Results: Firefighting gears effect on FF's heart rates





3. Results: Comparison between traditional and improved protections



Weight loss during tests,
grams in hour

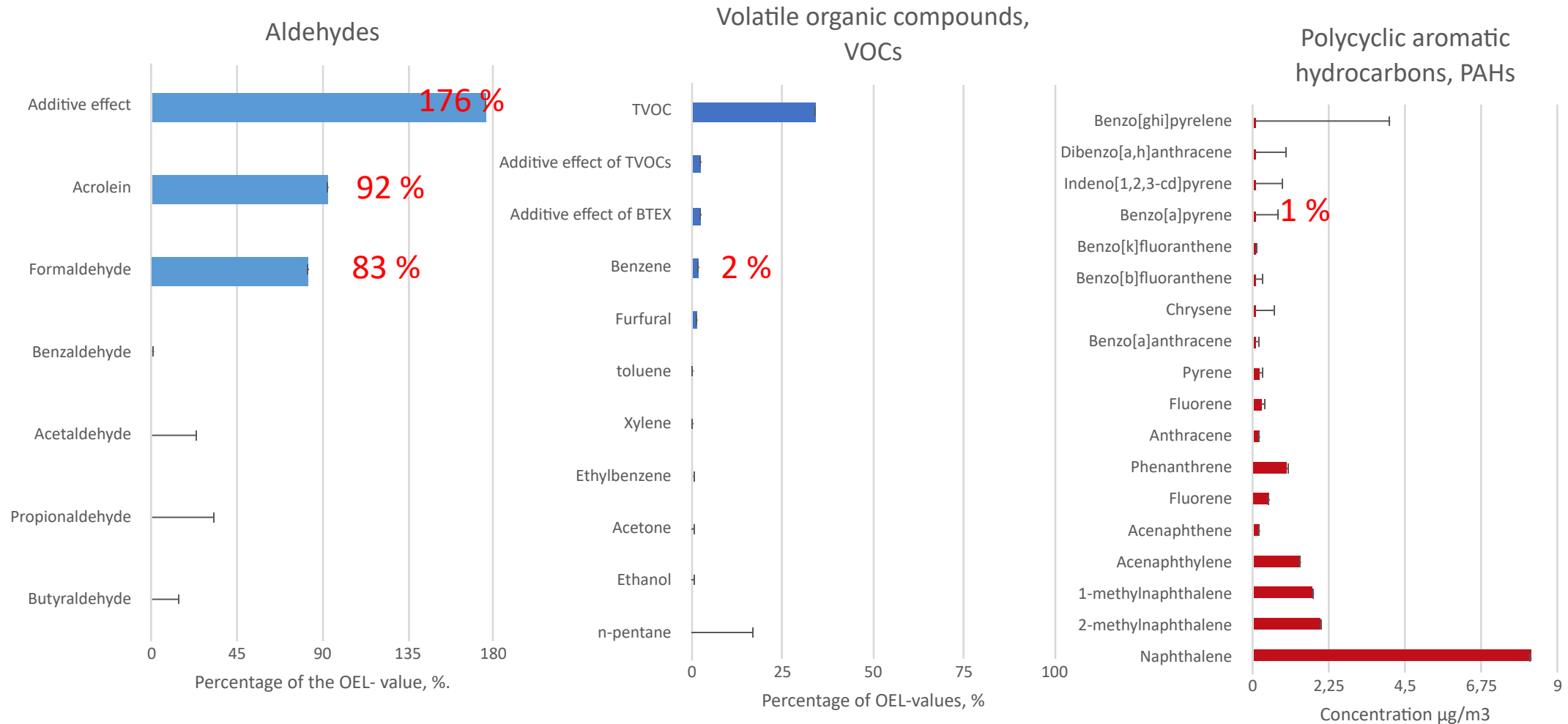
Sweat absorbed into the
clothing, gram in hour

Improved
Traditional

Grams in hour



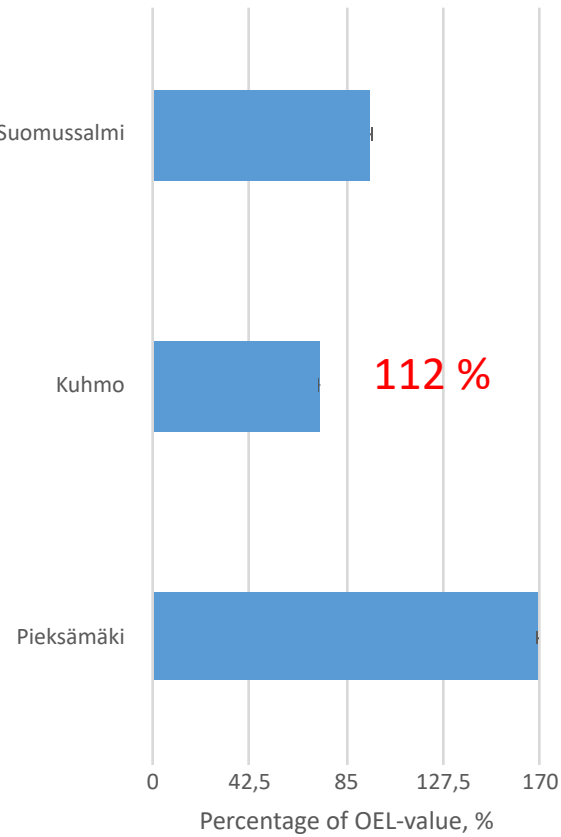
3. Results: Inhalation exposure to chemical agents among FF



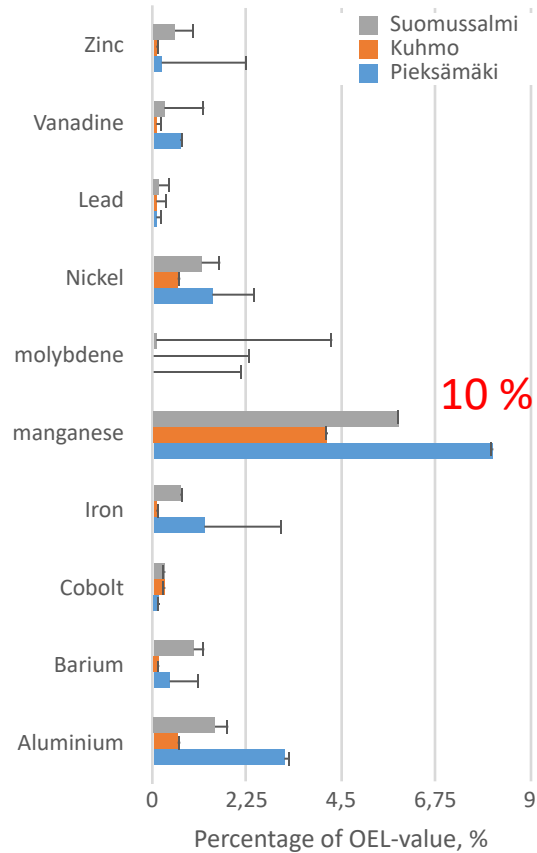


3. Results: Inhalation exposure to chemical agents among FF

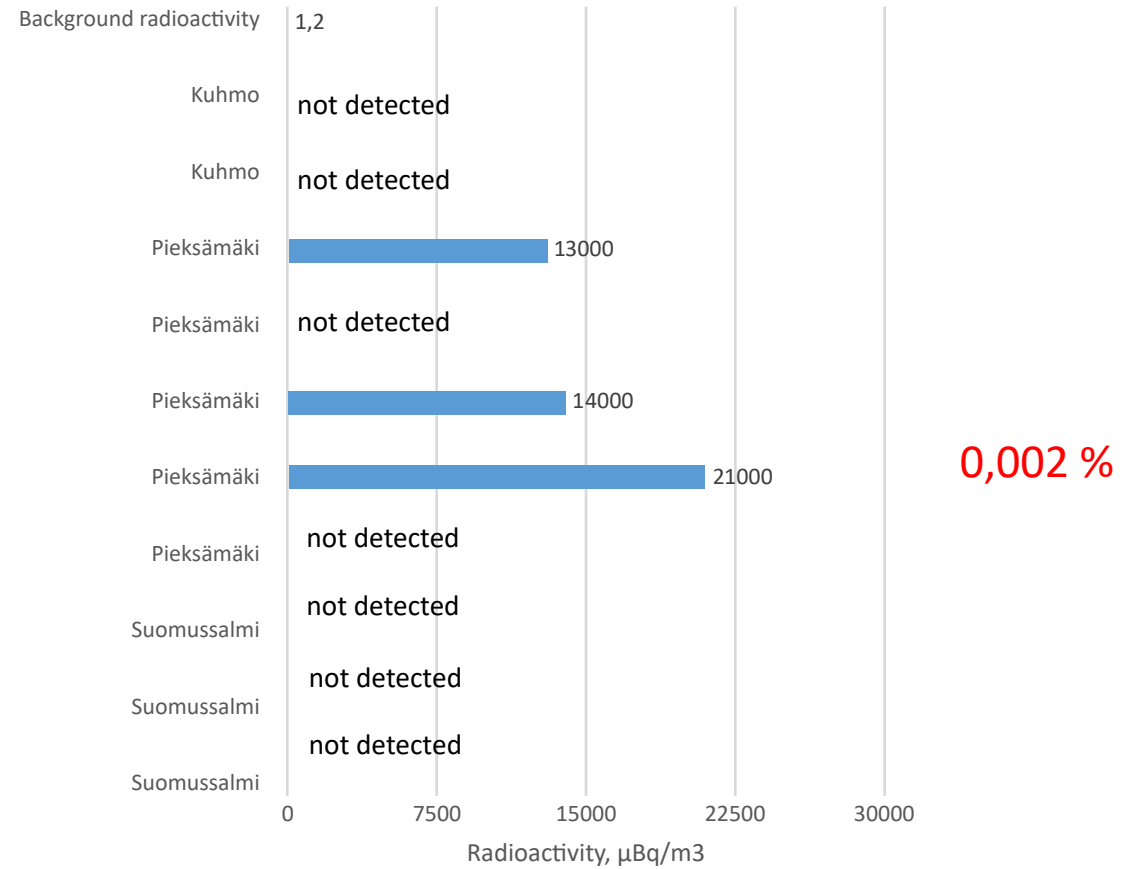
Inhalable dust



Metals in inhalable dust

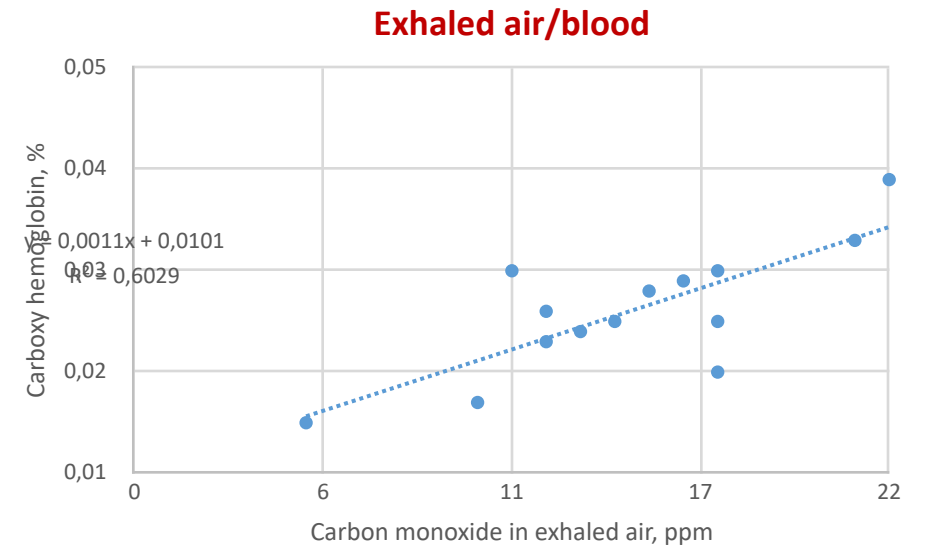
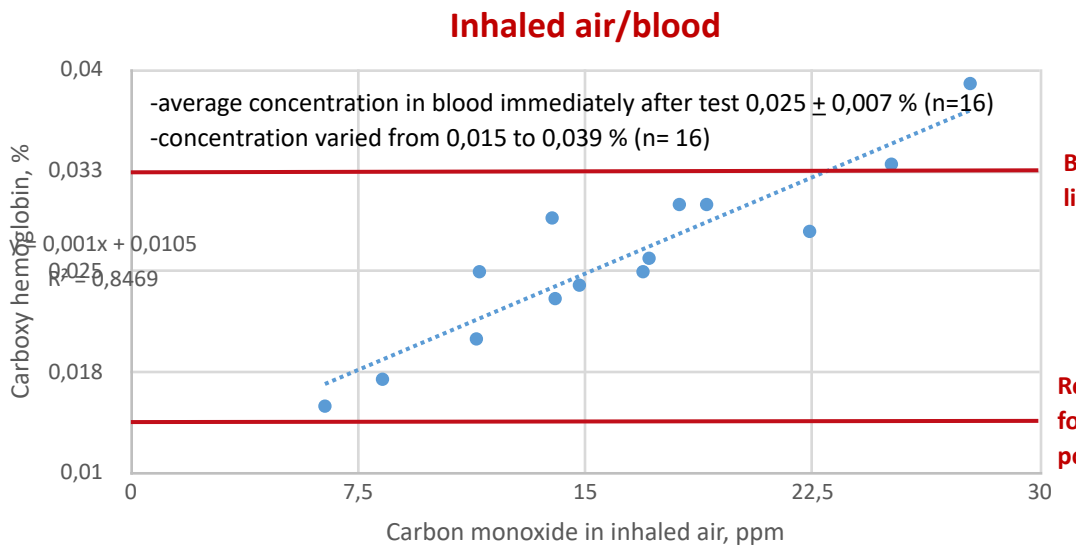
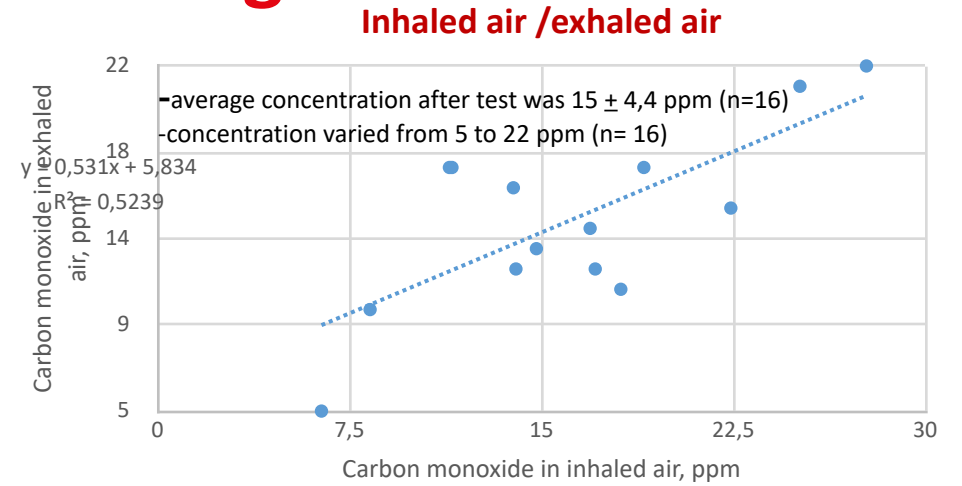
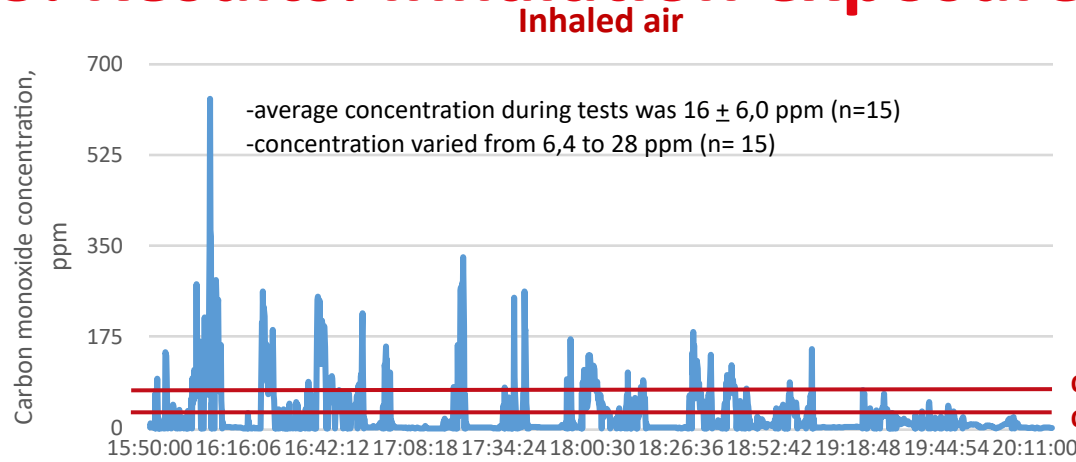


Cesium 137





3. Results: Inhalation exposure to CO among FF





3. Results: Dermal exposure to PAHs among FFs

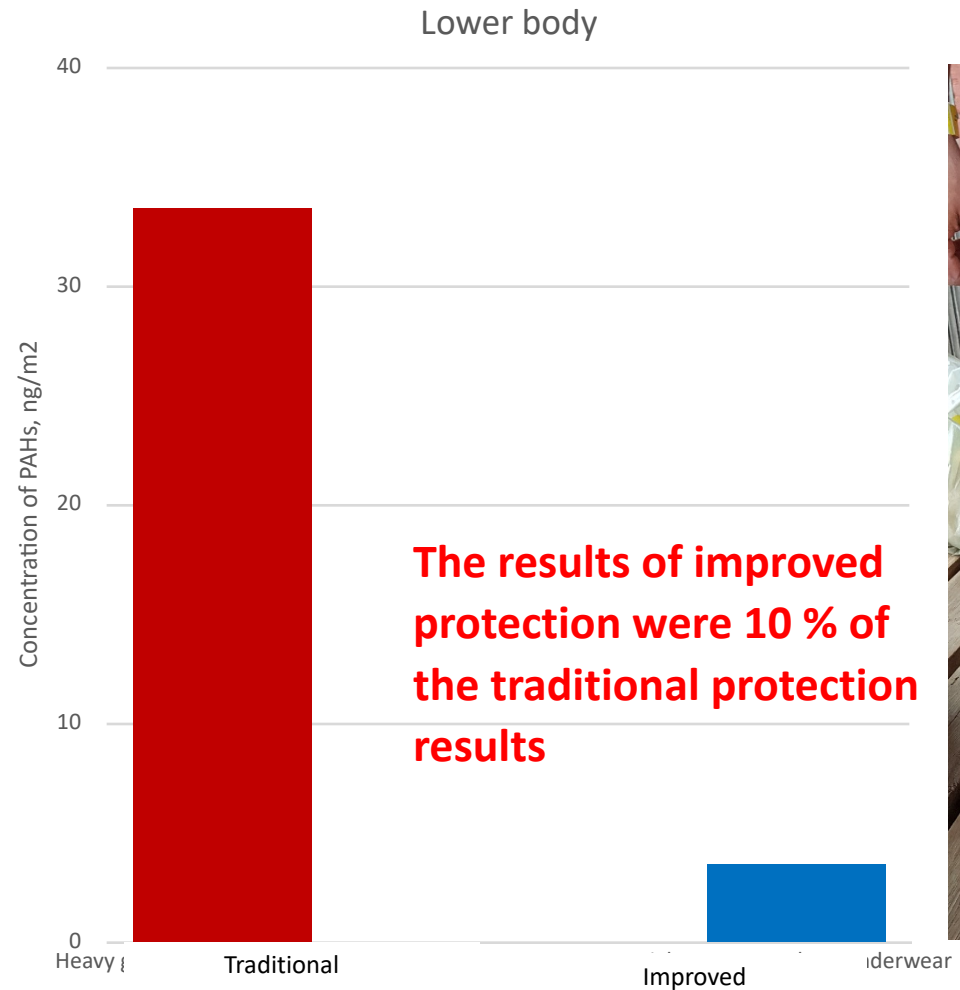
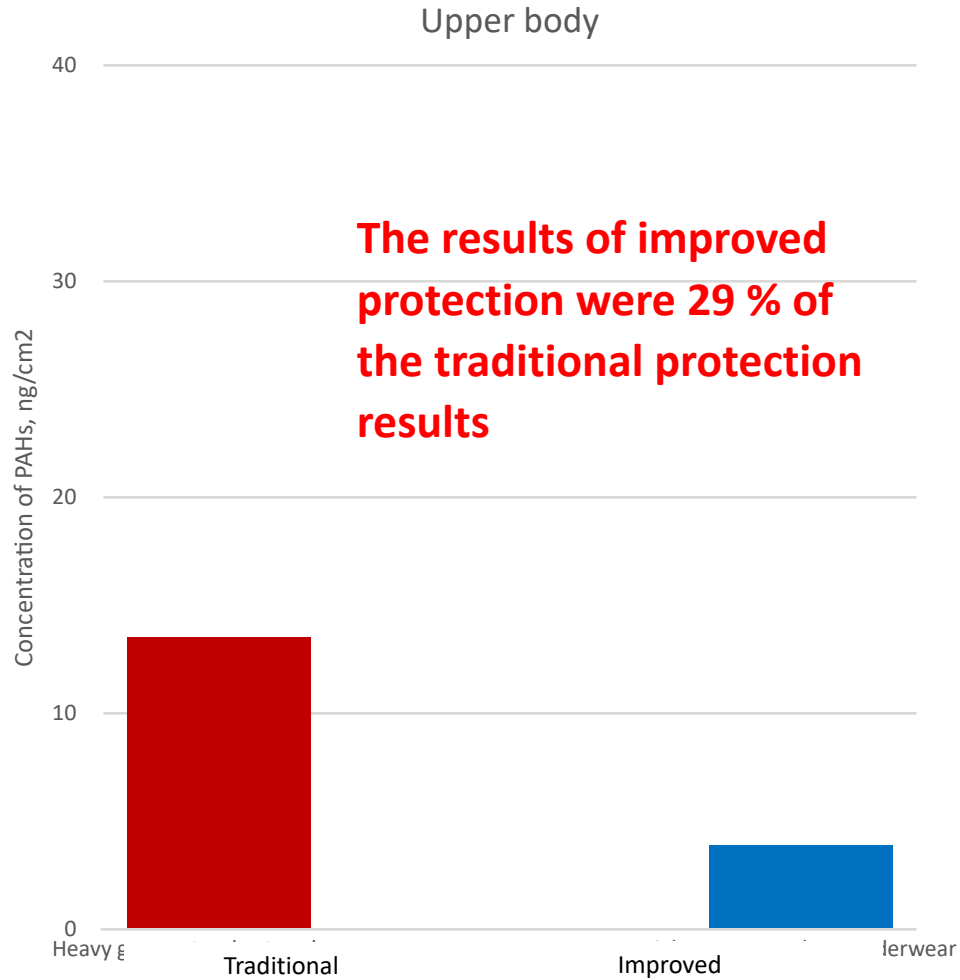


Photo: Juha Laitinen



3. Results: Total exposure to naphthalene among FFs

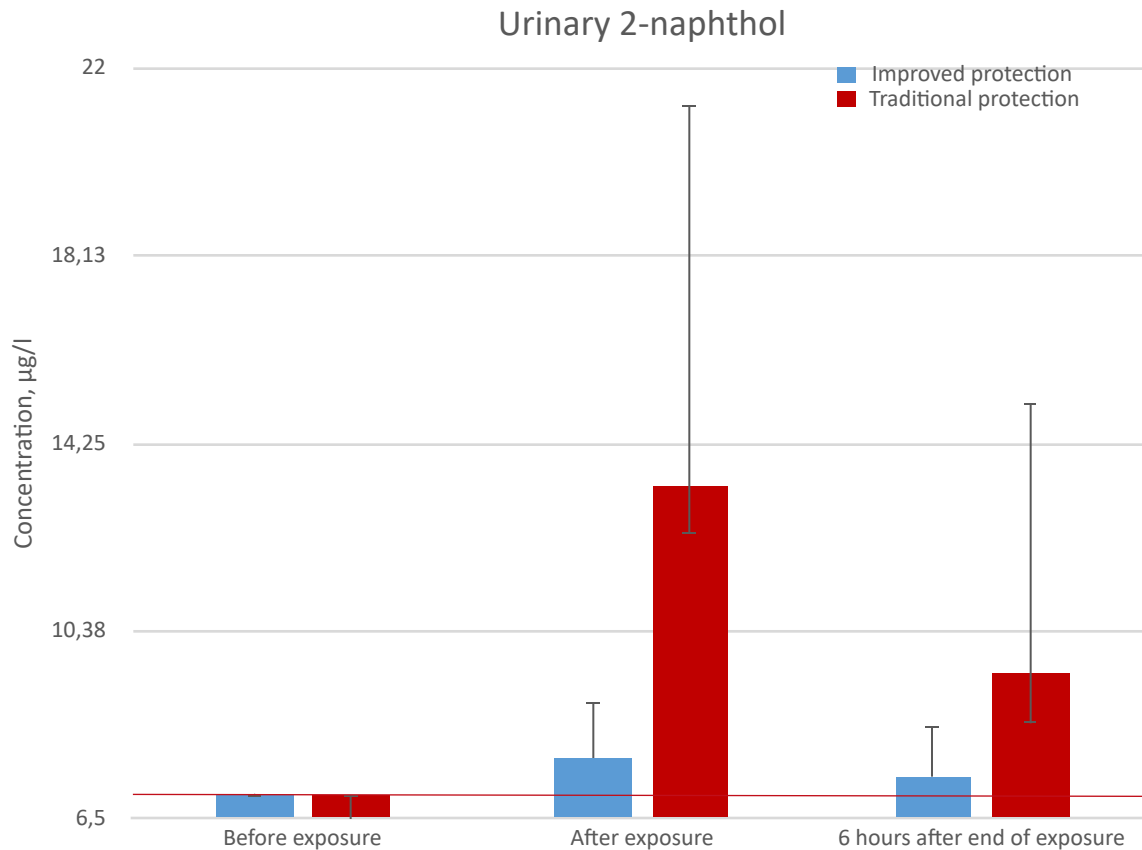
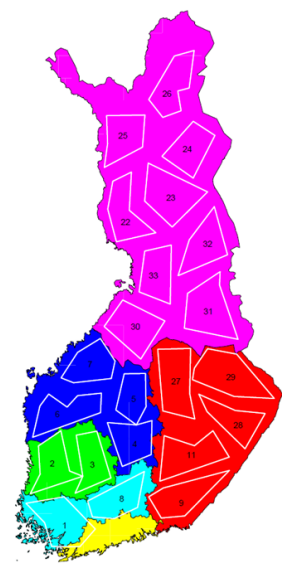


Photo: Juha Laitinen



4. Conclusion

❑ Preparedness

- Increase citizens' awareness of the fire risks at the forest fire seasons
- Better detection of fires with satellites, scheduled flights and reconnaissance flights
- Increase firefighters' preparedness
- Prepared protection plans for the most sensitive areas (nature reserves areas, peat production areas, forestry management area, shooting ranges, contaminated areas, wartime ammunition areas)
- Using fire sensitivity maps of vegetation and crown for prioritization sensitive areas for ignition
- To discuss with landowners the use of fire preventive actions (vegetation, fire protection lines and prescribed burnings)

❑ Situational awareness

- Real-time situational picture; ground profile, vegetation, weather data, fire and contaminant spread modelling
- A correct situational picture allows firefighters to choose right extinguishing tactics and techniques, to make an estimations of needed resources, assistance and evacuations
- At the same time, the workload and exposure are decreased, and occupational safety is increased



4. Conclusion

- ❑ **Choose of the best extinguishing techniques and tactics for each situation**
 - The workload can be reduced:
 - assisting the laying of the hoses by tracked ATV
 - using lighter 25 mm diameter hoses
 - When the soil allows it, chemical fire-retardant agents also provide a good opportunity to make a restriction line
 - When it is necessary to remove topsoil and make openings in the forest, excavators and forestry machines offer relief for this.
 - It is also worth using aircraft or helicopter extinguishing, modified forest harvester and fire extinguishing trailers to cut off the tip of fire.
 - The manual extinguishing work itself should always be done upwind whenever possible
- ❑ **Safety Officer**
 - Safety officers have the best information of situation and evacuation plans for firefighters.





4. Conclusion

❑ Adequate personal protective equipment

- Garments designed for wildland fires with long sleeved and legged underwear are the most recommendable
- Fan-assisted respirator is needed
- Carbon monoxide indicator for warning about too high concentrations is needed
- In the cut of the tip of the fire, firefighters must use pressurized breathing apparatus
- Heavier machines cabins must also be equipped with fresh air filters or with drivers' compressed air breathing apparatus
- Continuous online monitoring of firefighters (smart PPEs) is recommendable (location, exposure and biometric information)





4. Conclusion

❑ Maintenance and decontamination

- Water and food supply
- Get washed immediately after end of exposure
- Clean personal protective equipment

❑ Exhaled air monitoring

- To check exposure to carbon monoxide and is it at the safe level to continue working

❑ The length of the work shift must be reasonable

- The resources must be adequately dimensioned, because forest firefighting is physically demanding



Photo: Juha Laitinen



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