coldcut academy

Contamination Comparison

SAVE Tactics vs. internal BA Attack

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Abstract

Firefighters operate in hazardous environments where exposure to toxic and carcinogenic substances in fire gases poses significant health risks, including increased incidences of cancer and cardiovascular diseases. This report studies the effectiveness of the SAVE (Scan, Attack, Ventilate, Enter) tactic, deploying ultra-high-pressure water mist and controlled ventilation before entering and retaking the fire compartment, in reducing toxic exposure compared to traditional breathing apparatus (BA) internal attacks.

We conducted comparative tests at the Guttasjön Fire Fighting Training Facility, using a 40-foot container as the fire compartment. The tests evaluated two firefighting methods: the conventional standard operation BA-attack and the SAVE tactic, which involves cooling fire gases externally with water mist and ventilating the fire compartment before firefighter entry. Firefighters' exposure to contaminants was measured using samples from their protective equipment and analysed by gas chromatography-mass spectrometry (GC-MS).

Results from the initial tests in July showed inconclusive differences due to procedural deviations. However, subsequent tests in December, where proper SAVE procedure were followed, showed a clear reduction in contaminant levels, particularly polycyclic aromatic hydrocarbons (PAHs) such as phenanthrene and fluoranthene. The SAVE tactic significantly reduced the magnitude of contaminants and improved air quality, visibility within the fire compartment and temperature, suggesting a safer working environment for firefighters.

This study highlights the potential of SAVE tactics to improve firefighter safety by reducing exposure to toxic substances. Future research should include validation of the results and for instance comparative studies of physical absorption of substances between standard BA-attack and the SAVE tactic to highlight effects of a change in work-methods. The results underline the importance of tactical measures to minimise health risks and improve operational efficiency and safety in firefighting.

1 Introduction

It's widely recognized that the working environment for firefighters is hazardous, with fire gases containing poisonous and carcinogenic substances. This fact is supported by numerous studies and research reports highlighting the increased risk of firefighters developing cancer.

Furthermore, regular exposure to high temperatures has been associated with a higher likelihood of cardiovascular diseases, as indicated by a report by the American Heart Association.[1]

To mitigate the risks associated with exposure to toxic environments, a safer approach involves fighting fires from the outside. This method entails cooling the hot and toxic fire gases externally until they reach a manageable temperature, at which point firefighters can enter to extinguish the initial fire. This approach significantly improves the environment within the enclosure, both visually and in terms of air quality.

This report aims to provide concrete evidence of the enhanced environment achieved through the SAVE tactic in contrast to a traditional breathing apparatus (BA) attack. To achieve this, comparative tests have been carried out.

The Cobra system is an ultra-high-pressure water misting system. As such, it is an enabler of changing the conditions in certain common fire situations. When used correctly, it is possible to introduce a very fine water mist from a relatively safe position external to the fire compartment. The introduced water mist will reduce the temperature in a steady state under ventilated fire, normally from 500 C to 100 C.[2] This opens for actions which would not be possible in prior, given the fire dynamics: By substituting the hot fire gases to cool fire gases mixed with (inert) steam it is possible to access the fire compartment without risk of fire gas ignition. Then, the steam/gas mixture is possible to substitute to external air by ventilating the fire compartment in a controlled fashion before committing firefighters to the fire compartment. The result is a firefighter work environment which includes clear eyesight, substantial lower temperatures, and a minimum of exposure to toxic gases.[3]

Clear eyesight and low temperatures have been experienced and measured thousands of times, at trainings and in real interventions. In 2014, The Royal Swedish Navy conducted tests of implementing tactical ventilation to rid smoke from fire compartment and to increase visibility using both positive pressure ventilators and installed ventilation systems[4].

However, the exposure to toxic fire gas have not yet been examined, even though the hypothesis has been present due to the obvious change in the fire compartment working conditions using the SAVE tactics.

Based on the results from the recent studies on firefighter health with respect to toxic exposure and implemented regulations, Cold Cut System decided to conduct an indicative study on the difference in toxic exposure to firefighters by comparing toxic residue using BA attack and a tactic based on the description above.

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[1] (Riggs, et al., 2024)
[2] (Gsell, 2010)
[3] (Lindström, Försth, Ochoterena, & Trewe, 2014)
[4] (Osbäck & Trewe, 2017)

2 Background

With respect to firefighting, the Swedish Work Environment Authority notes in their regulations AFS 2007:7 that “Internal Breathing Apparatus [BA] attack is the most dangerous job allowed in Sweden and is also one of the most physically demanding. The paragraph [§5] should be interpreted so that BA-attack is primarily a life-saving effort. The risks involved are e.g. exposure to heat (cardiac stress), risk of physical injury due to limited eyesight and exposure of carcinogenic substances. The latter is supported by several studies worldwide[5] and subsequently a number of cancer forms have been declared as occupational health issue in several countries.[6] Internal extinguishing by BA-attack should therefore be avoided as far as possible. External firefighting should be considered as the first option.”[7]

Thus, if there are no life to save, there need to be a very good reason for a Fire & Rescue Service, as an employer, to commit firefighters to a fire where there is no life to save. None the less, we frequently have reports about casualties involving firefighters regardless there was no life to save. In praxis, fire and rescue services uses internal attacks on routine even if it is not the safest or most effective attack, NIPV concludes: “Research shows that, under pressure of time, people experience a narrowed consciousness, partly due to the effects of adrenaline, which causes them to overlook many vital clues. In actual practice, people tend to follow a routine, even if there are clear signs that this is not advisable.”[8]

In 2016, the Swedish Defence Research Agency made a study commissioned by the Swedish Civil Contingencies Agency on dermatologic absorption of polycyclic aromatic hydrocarbons (PAH) on firefighters during firefighting training. The study showed that PAH substances deposit on skin during a standardized BA-attack exercise. The PAHs were absorbed into the body and could be traced with an increased excretion of their metabolites in urine. On average, an exercise session generated an eight-fold increase in both PAHs in skin deposition samples and excreted hydroxypyrene in urine at the individual level.[9]

The Directive EU 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work clearly states that an employer should substitute toxic substances to non-dangerous or less dangerous substances if technically possible. The Directive goes on, following the *Hierarchy of Controls* until it reaches the last resort – personal protection equipment (PPE).[10]

The Swedish initiative Healthy Firefighters (The Skellefteå Model) is supported by the Swedish Civil Contingencies Agency.[11] Healthy Firefighters promotes separation of PPE and other equipment after interventions, in vehicles and at the fire station (separating clean and dirty areas), minimizing firefighters to exposure after the interventions. It also promotes development and use of personal protection equipment, such as second layer garments, to minimize permeation of toxins during interventions. It is promoted and adopted in many countries as means to protect firefighters against exposure of toxic substances from interventions and hot exercises.[12]

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[5] (IARC Monographs, 2023)
[6] (IARC Monographs, 2023)
[7] (Arbetsmiljöverket, 2019)
[8] (Weever, Baaij, Huizer, & de Witte, 2018)
[9] (Rattfelt Nyholm & Wingfors, 2016)
[10] (Directive 89/391/EEC, 2020)
[11] (Stefan Magnusson, David Hultman, 2015)
[12] See for instance: (Florida Firefighters Safety & Health Collaborative, 2024), (FeuerKrebs, 2024) (Brandmenn mot kreft, 2024), (Brandmännens Cancerfond, 2024), (Healthy Firefighters, 2024)

In a 2020 follow up study on approximately 30000 professional firefighters in the USA, the results added previously unreported excess in non-Hodgin's lymphoma to lung-cancer and leukaemia to the cohort compared to the general population.[13]

In 2022, the International Agency for Research on Cancer (IARC) finalized their evaluation of the carcinogenicity of occupational exposure as a firefighter. The occupational exposure as a firefighter was classified as "carcinogenic to humans" (Group 1) based on sufficient evidence for cancer in humans.[14] As a consequence in 2024, the Health and Safety Executive (HSE) in UK has set out plans to start inspecting fire and rescue services to regulate measures taken to protect firefighters from carcinogens.[15]

In 2023, the German Fire Brigade Association released the recommendation "Operational principles for hygiene in firefighting", in German "Einsatzgrundsätze zur Hygiene im Brandeinsatz", with the objective introduce minimum standards for minimizing health hazards from smoke and combustion to avoid unnecessary exposure and spread of contamination. Most of the recommendations presented includes protective measurements after intervention, but an innovative approach is a recommendation to substitute the toxic exposure to firefighters to a less toxic environment by tactical measures. Here they mention attacks from outside the fire compartment, use of cutting extinguisher and tactical use of ventilation in conjunction with interior attack.[16]

2.1 Aim & objective

The aim is to provide a comparison between toxic substance exposure to personal protection equipment used in two different firefighting tactics – breathing apparatus internal attack and an internal attack preceded by fire gas cooling and tactical ventilation, performed as an external attack.

The objective is to provide proof of a safer tactic for fire service personnel to combat primarily under ventilated fires by reducing risks in prior to extinguishing the seat of the fire, with respect to exposure of toxic and/or carcinogenic substances.

2.2 Delimitations

The tests carried out only concern a contamination comparison between the SAVE tactic and the so-called standard operating routine for internal firefighting (BA attack). Furthermore, the tests only include a comparison between the number of contaminants that the crew were exposed to in each method and tactic. The analysis of contaminants was according to a screening method, indicating an order of magnitude of substances detected.

[13] (Pinkerton, et al., 2020)
[14] (IARC Monographs, 2023)
[15] (Fire Brigades Union, 2024)
[16] (Schubert & Reuter, 2023, p. 4; Schubert & Reuter, 2023)

3 Theory

According to the risk management process in ISO 45001:2023, which follows the Plan-Do-Check-Act principles, occupational health and safety risks should be identified and assessed, checked and mitigated.[17] Levels of mitigation are described in the method of Hierarchy of Controls which names Elimination, Substitution, Engineering Controls, Administrative Controls and Personal Protective Equipment (PPE) as means of controls, named in decreasing efficiency levels. In this work model, PPE is the last resort when it comes to efficiency. As you climb the Hierarchy of Controls, the efficiency increases. The Substitution principle in the Hierarchy of Controls encourage Employers to implement working environments which expose the employers to less hazardous materials or work process which involves a work environment which for instance includes less temperature or better visibility.[18]

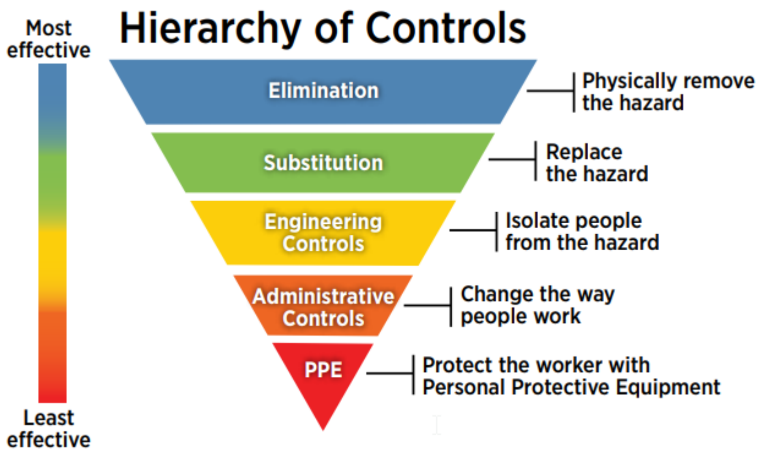


Figure 1 Illustration from OSHA showing Hierarchy of Controls

The theory used in the tests and trials are based on the Hierarchy of Controls. More specifically, substituting a hazardous work environment which involves exposing firefighters to a wide range of hazardous substances, including carcinogenic substances, to an environment with less exposures to hazardous substances. The hypothesis is that less exposure to toxic environment minimize long term health risks such as cancer for firefighters.

[17] (International Organization for Standardization, 2023)
[18] (OSHA, 2023)

4 Method

The test regime was set up to compare the exposure of hazardous substances with firefighters using two different tactics during a standardized intervention. The tactics are described as BA-attack and SAVE.

The firefighters who participated in the tests were experienced professionals actively serving in Swedish fire and rescue service organisations. They have extensive knowledge of Cobra as they are Cobra Instructors.

4.1 BA-attack

BA-attack is the standard tactics for internal attack to reach a fire seat in a building or compartment. The standard set up and method varies from country to country, from fire service to fire service and even between fire fighters. Normally the BA-attack includes two firefighters which enters the compartment and an outside group leader which is responsible for the communication with the BA-team and control of the whereabouts and status of the BA-team. The team has normally a maximum reach (depending on hose lengths or regulations) and an action time depending on the air supply in the breathing apparatus. The objective of a BA-attack may vary, including rescue operation (persons reported missing) or locating and extinguishing a fire. In this scenario the objective was to locate and extinguish the fire in a safe way, according to standard procedures.

4.2 SAVE tactics

SAVE tactics includes entering the fire compartment with breathing apparatus but is preceded by cooling fire gas with an ultra-high pressure water misting system (UHPS) from an external relatively safe position. To have a good effect of the UHPS, the seat of the fire is identified by using Thermal Imaging Camera or other methods from the outside of fire compartment. After the fire gas is cooled (typically from 500°C to less than 100°C), the smoke and steam is ventilated in a controlled way using Positive Pressure Ventilation (PPV) at the entry point and by opening a controlled exhaust point beyond the seat of the fire vis-à-vis the entry point. When the smoke and steam is ventilated, the BA-crew may follow behind the steam with clear visibility to the seat of the fire. The seat of the fire may then be extinguished. SAVE is a mnemonic acronym of the actions Scan, Attack, Ventilate and Enter.

For further discussions on fire gas cooling, see *Assessment of fire suppression capabilities of water mist*[19], *Spray Characterization of the cutting extinguisher*[20] and *CFD Calculations of the Cutting Extinguisher*[21].

4.3 Two test dates

Initially, there was only one test date planned. However, during the first test date, there was a misunderstanding in the procedure by the firefighters carrying out the procedures. At the first test date, there were two main issues which affected the results:

- The BA-attack was not carried out in a safe way (did not follow procedures), probably due to the firefighters' previous knowledge of the fire compartment.
- The SAVE tactics tests were in a similar way not carried out in a safe way, as the firefighters entered the compartment before the steam/smoke was ventilated.

Apart from this, the test procedures were identical.

[19] (Gsell, 2010)
[20] (SP Technical Research Institute of Sweden, 2012)
[21] (SP Technical Research Institute of Sweden, 2014)

Thus, the results from the laboratory analysis of the test samples were inconclusive and a second test date was scheduled. However, the results from the first test date is also presented in this report.

5 Materials

5.1 Planning with test lab

Prior to setting up the test regime, the set up and the method were discussed with representatives of the test lab used, the Swedish Unique Solution Laboratory AB (SUSLAB). SUSLAB is a chemical analysis lab and consulting company which resides in Borås and Gothenburg, Sweden.[22]

The analysis method used on the test samples was a semi-quantitative screening using gas chromatography-mass spectrometry (GCMS) to extract organic substances. Further the GCMS results was searched through the NIST library in combination with spectral deconvolution using ADMIS software for verification.[23]

5.2 Fire compartment set-up

The testing grounds were set at Guttasjön Fire Fighting Training Facility which belongs to SERF, a Swedish Fire and Rescue Service with headquarters at the City of Borås in the Southwest of Sweden.[24]

The training grounds are equipped with several objects, including high rise, accident scenes and hot fire training compartments. One of the hot fire systems includes a 40-foot container used for UHPS training. This container was used for the test described in this report.

The container was placed in an east-west direction and has four openings. A door in the eastern short side, a door in the northern long side, a double door to the west and a southern door to the rest of the system across from the door in the northern long side. The southern door was closed during the tests.

Inside the western double doors, the seat of the fire was placed. Prior to initial tests at both test dates, the container was heated by burning 10 wood pallets to approximately 400°C to pre-heat the compartment and to minimize residue from previous trainings (in the trainings, normally only wood pallets, shredded paper and diesel is used).

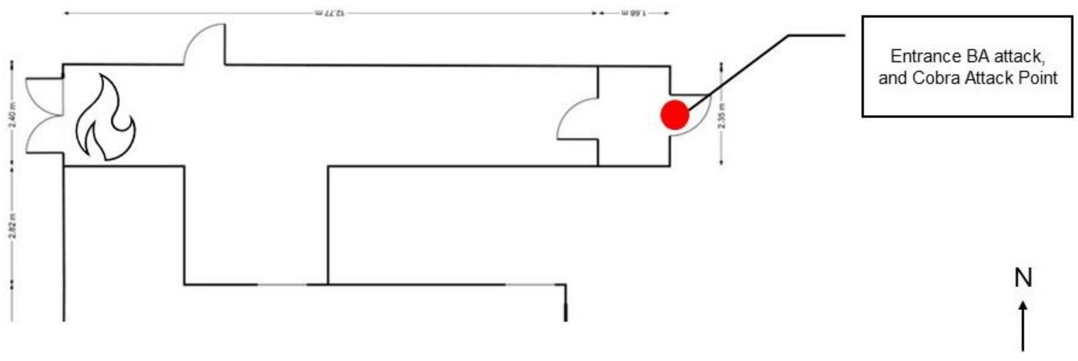


Figure 2 Rough sketch over fire compartment

[22] (Swedish Unique Solution Laboratory AB, 2024)
[23] (SUSLab, 2024)
[24] (Södra Älvsborgs Räddningstjänstförbund, 2024)

Figure 3 Fire compartment

5.3 Fire load

Each burn (both test days) was loaded with 10 dry pallets made of wood (non-impregnated). The loads were spiked with objects of material normally found in residential buildings: a computer keyboard and PET plastic containers. On the first test date a PVC garden chair was used. On the second test date plastic buoys and additional plastic containers were used. The difference in spiking objects, depended on the availability of the garden chair at the supplier, as the first test date was in July, while the second test date was in December. The objective of using spiking objects in the fire load was to simplify identification of substances left on the test samples. Since the objective of the test was to compare levels of residual substances on the samples of two tactics, the variation of spiking objects was deemed to be of no significance to the result.

Figure 4 Fire load first test

5.4 Test sampling

Each firefighter was equipped with two test samples pieces. The sample cloth was made of outer garment of a used and washed (10 times) turn out gear and a washed piece of cotton sheet. The size of the samples was 7 cm by 12 cm. The samples were fastened to a larger piece of cotton sheet before fastened to the upper arms of the firefighters PPE. After each test the samples were collected and folded separately into aluminium foil which in turn was put in zip-lock plastic bags. Each bag was marked with type of test, individual and type of garment.

In total 2 sets of 16 samples along with two blank zero-samples (one PPE and one cotton sheet) from each test date were admitted to gas chromatography–mass spectrometry. The samples were delivered within 48 hours to the test lab.

Figure 5 Sample set up on firefighters

Figure 6 Samples after operation

5.5 Cutting Extinguisher

For the test, a Cobra C360 system was used. The system delivers 58 litres per minute at a pressure of 300 bar (30 MPa) at the nozzle, supplying water mist to the fire compartment with a Sauter Mean (d_{32}) distribution of less than 200 micron.[25]

[25] (SP Technical Research Institute of Sweden, 2012)

6 Test realisation

The tests comprised two test dates, one in July and one in December (2023)

Each test date carried out four test burns, two applying standard BA-Attacks and two applying SAVE tactics.

The crew set up for all tests were two BA crew and one BA crew commander. The BA crew commander also handled the exhaust of the fire object and the ventilator in the SAVE tests.

Prior to the tests, the BA team was briefed about the series of comparative tests. Their objective was to suppress the fire following standard procedures, assuming no persons were reported missing using standard BA-attack and SAVE tactics.

6.1 July tests

The first two tests used BA-attack. Prior to entry into the fire compartment, temperatures reached approximately 400°C, accompanied by dense, black smoke, significantly impairing visibility.

After extinguishing the fire in an internal attack, the team finished the operation. The total duration in the fire compartment was approximately 4.5 minutes. The test and the sampling were repeated twice.

The second two tests used SAVE tactics.

When the temperature reached approximately 400°C, the cutting extinguisher was deployed through a closed door to cool the fire gases. The time of Cobra deployment was just short of 60 seconds and lowered the temperature to 70°C. The decrease in temperature was shown on a thermocouple connected display.

The ventilator was started, and the BA crew entered to supress the remnants of the fire. The team spent approximately three minutes inside the compartment. *However, the firefighters entered the fire compartment before the steam was ventilated out, exposing them to steam mixed with smoke.* Again, the tests were repeated two times.

The analysis showed inconclusive results, which opted for a second round of tests where more detailed instructions was given to the firefighters.

In the after-action review, the firefighters indicated that the fire object was known to them, they knew where the fire was. Thus, they acted outside of the procedures, both in the BA-attack and using the SAVE tactics. In the BA-attack, they did not follow the wall, or look for traps, etc, as the path was known. Using SAVE, they did not wait for the ventilator to push out the steam before entering the fire compartment.

6.2 December tests

The December bundle of tests was in principle repetition of the July tests, but more attention was paid to follow procedure in both BA-attack and SAVE tactics.

In the two BA-attack tests, again the fire reached 400°C before the BA-crew entered the object. This time the internal attack followed procedures which added a minute for the crew to reach the seat of the fire. In total they were inside 5.5 minutes, on each occasion.

In the two following SAVE deployments, the Cobra was used to lower the temperature from 400°C to 70°C in just short of 60 seconds. After the ventilator was started and the exhaust was opened, it took 60 seconds to clear the compartment of steam. Then the BA crew entered the object with clear visibility, extinguishing the remnant of the fire. In total the crew was inside the fire compartment for two minutes, summing up the total intervention time to 4.0 minutes.

7 Results

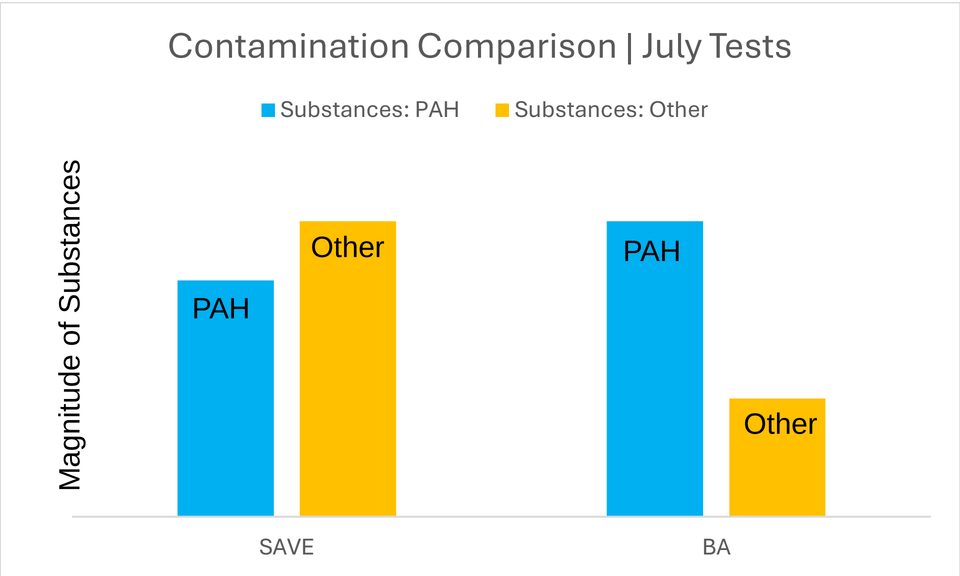
The diagrams presented in this chapter are based on the results of the analysis of the contaminants present on the garment after the extinguishing efforts. Through a gas chromatography-mass spectrometry (GC-MS) the lab identified and quantified substances present in the smoke during each test round. Due to incorrect execution in the first test round, we had to repeat the tests, resulting in two sets of analysis data. To enable a comparison between the two test rounds, we focused on the substances that appeared in both rounds. For a more comprehensive analysis, please refer to the appendices in this report.

We selected these substances to compare their presence and amount. Since the analysis does not provide exact quantitative values, but rather an indication of which substances are present and their relative amounts, we chose to present the results as magnitude comparisons. These magnitudes give an estimate of the quantity of each substance relative to the other substances detected.

To make it easier for the reader, we categorized the substances into two main groups: polycyclic aromatic hydrocarbons (PAHs) and other substances. In the 'other' category, there are substances with varying toxicity. These substances include volatile organic compounds (VOCs) and aromatic compounds, depending on their chemical structure and properties. They have different potential health effects ranging from skin irritation and respiratory issues to more serious long-term health risks. This categorization is important because PAHs are known for their serious health risks. The diagrams thus illustrate a magnitude comparison of the substances present, with particular attention to the potential health hazards associated with PAHs.

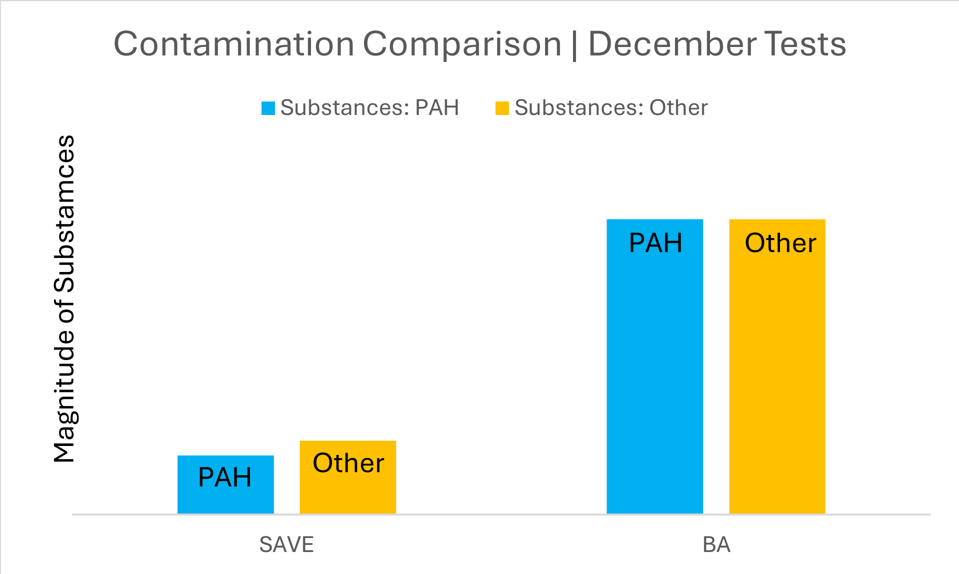
The results of the July tests show that the levels of PAHs are higher in BA compared to SAVE, but the levels of other substances are higher in SAVE compared to BA. This can be explained by the fact that the temperature had been lowered due to the addition of water mist in the room, but some water-soluble substances had condensed and were prone to sticking to the crew's garments. In the case of the BA attack, some water-soluble substances were indicated since water from fire hose was used to spray hot surfaces during the interior attack.

Table 1 Comparison of magnitude of substances in July test



The results from the tests in December show a clear difference in the magnitude of substances present at each incident. The magnitude of PAHs stuck on the crew during the BA attack is higher compared to SAVE, likewise the magnitude of other substances is higher at BA compared to SAVE. This can be explained by the fact that the fan was used at SAVE and the residues were ventilated out before entering and extinguishing the fire.

Table 2 Comparison of magnitude of substance in December test



8 Discussion and conclusion

In the first test occasion, the comparative results were inconclusive, since the cooled fire gases were not ventilated before the firefighters entered the building. Because of this situation, a second test date was set up, to carry out the test according to the SAVE tactics.

No major differences could be detected between the two tactics used. Both methods indicated high exposure of the poly aromatic hydrogens (PAH) phenanthrene and fluoranthene. In addition, in tests where high pressure water mist was introduced, water soluble substances with low boiling points were found.[26]

However, the result from the first test indicated that it is of importance to ventilate the compartment in prior to entrance, not only to get a clear eyesight, but to minimize the exposure of fire gases.

The results from the follow-up second test showed a significantly less presence of substances in the samples from where the Cobra SAVE tactics were used in comparison with standard BA-Attack. In the samples from the standard BA-attack, three known carcinogenic PAH substances were detected: phenanthrene, fluoranthene and acenaphthene. These substances were not detected in the Cobra SAVE test samples. The result was that by using the Cobra SAVE tactics, a general lower quantity of substances was detected and that the PAH substances were not detected at all.[27]

In conclusion, the tests indicates that it is possible to substitute a toxic work environment for firefighters to a significantly less toxic work environment by using the SAVE tactic; external attack with cutting extinguisher (UHPS) to cool hot fire gases, ventilating the steam/smoke before entering and retaking the compartment. In addition to reducing the toxic exposure to firefighters, the SAVE tactics reduce the temperature significantly and offers clear eye-sight in the compartment.

8.1 Further studies

While this study demonstrates the significant benefits of using Cobra and ventilation to reduce temperature, improve visibility, and lower the magnitude of contaminants in fire compartments, there is need of more research to enhance understanding and application of these findings. Since this study has a relatively low sample base, the indications should be validated by third parties in volume studies. Comparative studies of physical absorption of substances between BA-attack and the SAVE tactic could further highlight effects of a change in work-methods.

These studies are based on under-ventilated fires; future research should also consider ventilated fires. Additionally, the building materials should be taken into account, as the composition of the structure may influence the outcomes. For example, materials with high insulation properties generate more heat, which can potentially lead to increased contamination through absorption.

By addressing these areas in future research, we can build on the current findings to further enhance the safety, effectiveness, and environmental sustainability of firefighting practices. This will contribute to better health outcomes for firefighters and improved fire suppression strategies overall.

[26] (SUSLab, 2024)
[27] (SUSLab, 2024)

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COLD CUT SYSTEMS: CONTAMINATION COMPARISON TEST

Report 2024-04-03

Swedish Unique Solution Laboratory

Preface

Introduction:

Two tests were performed to evaluate differences in the amount and nature of organic substances present in smoke from conventional fire extinguishing methods compared to the Cobra water jet.

This compiled report consists of the two original separate reports and a joint conclusion at the end. The initial experiment was repeated, since video footage showed that an incorrect procedure was used in this test. Results are still included since they give information on what happens when the procedure of venting out smoke and watermist using a fan was omitted in the waterjet procedure.

The two tests were performed in a similar way, however in the second test it was not possible to obtain the same outdoor furniture, made of PVC, which evidently affected the presence of some organic substances in the smoke.

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

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Description of the laboratory process:

As test samples, pieces of standardised dimensions prepared from cotton fabric and PPE-fabric were used. The test patches were delivered to the laboratory, individually wrapped in aluminium foil and had been kept cool and dry since the extinguishing test.

For extraction each test patch was loosely rolled and placed in a cylindric glass vial capped with a teflon lid. Using this setup the whole fabric patch could be immersed in a small volume of ethyl acetate. Extraction was performed at room temperature for extended time, three days, to facilitate dissolution of larger solid particles.

The analysis of the ethyl acetate extract was performed using GC-MS in full scan mode. The instrument used was an Agilent 240 ion-trap mass spectrometer suited for full scan measurements coupled to an Agilent 7890B GC with MMI inlet and using large volume injection. The supplied blank material was treated in exactly the same way as the sample test patches and the full scan chromatogram of this blank material was used for background measurements. Only substances present in the test patches but absent in the blank material were listed in the results table.

This analysis is a screening method and is performed uncalibrated, hence, no exact amounts of the detected substances can be calculated.
To indicate abundance of substances, (+)-signs are used in the table. These signs are used also, when the same substance is present in several samples, to show the relative abundance between the samples, using 1-3 (+)-signs. When a substance not is detected in a specific sample it is indicated by (-)-sign.
Note, that as each substance has its own sensitivity in the analysis, no real comparison in relative amounts between different substances is possible. The relative comparison is only valid for the same substance in different samples and not for comparisons substance to substance.

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

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Analysis Report 20230910

Client: Cold Cut Systems AB

Address: P.O. Box 10181
SE-434 22 Kungsbacka, Sweden

Reference: Anders Trewe

Our reference: Anders Blom

Analysis:	Screening of organic substances collected on test patches
Method:	Qualitative analysis, screening using GC-MS for extractable organic substances. Library search using the NIST library with 400 000 substances combined with spectral deconvolution using AMDIS software for verification.
Sample preparation:	Test patches were extracted in ethyl acetate for 72 hours and intermittent shaking. Extraction performed in super-clean glass vials with teflon lid.
Date of analysis:	2023-08-18
Substrate:	According to table
Sample number:	According to table
Performed by:	Anders Blom/Alexandra Chukharkina

Samples

Sample number	Client ID	Substrate	Test	Person #
23043	T0-1B	Cotton fabric	blank	1
23044	T0-2B			2
23045	T3-1B		Cobra Save	1
23046	T3-2B			2
23047	T4-1B		Cobra Save	1
23048	T4-2B			2
23049	T1-1B		Standard	1
23050	T1-2B			2
23051	T2-1B		Standard	1
23052	T2-2B			2
23053	T0-1A	PPE-fabric	blank	1
23054	T0-2A			2
23055	T3-1A		Cobra Save	1
23056	T3-2A			2
23057	T4-1A		Cobra Save	1
23058	T4-2A			2
23059	T1-1A		Standard	1
23060	T1-2A			2
23061	T2-1A		Standard	1
23062	T2-2A			2

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

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Swedish Unique Solution Laboratory

Results test 1

Substrate: cotton fabric					
Substance	**CAS**	**Sample**			
		23045	**23047**	**23049**	**23051**
		23046	**23048**	**23050**	**23052**
2(5H)Furanone	497-23-4	+	+	+	+
Methyl cyclopentenolone	80-71-7	+	+	-	-
2-methylpenol	95-48-7	+	+	-	-
p-Cresol	106-44-5	+	+	-	-
Mequinol	150-76-5	+	+	-	-
3,4-dimethylphenol	95-65-8	+	+	-	-
3-Ethylphenol	620-17-7	+	+	-	-
Creosol	93-51-6	+	+	-	-
4-ethylguaiacol	2785-89-9	+	+	-	-
4-phenylbutyronitrile	2046-28-6	+	+	-	-
Dibenzofuran	132-64-9	+	+	-	-
Naphazoline	835-31-4	+	+	+	+
Triethylphosphate	78-40-0	-	-	-	+[1]
Azumolene	16462-98-9	+	+	+	+
2,6-diisopropylnaphthalene	24157-81-8	+	+	+	+
Phenanthrene	85-01-8	+	+	+	+
di-isopropylnaphthalenes	-	+	+	-	-
2,3,4,6-Tetramethoxystyrene	48153-74-8	+	+	-	-
Sebacia acid esters	-	+	+	+	-
2-Phenylnaphthalene	612-94-2	+	+	-	-
Neophytadiene	504-96-1	+	+	-	-
Fluoranthene	206-44-0	+	+	+	-

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

Pyrene	129-00-0	+	+	+	+
Benzoic acid esters	-	+	+	+	+[2]
Retene	483-65-8	-	-	+	-
Phthalates	-	+	+++	++	+

[1]- only detected in sample 23052 (person B)
[2]- notably higher presence in sample 23052 (person B) vs sample 23051

Substrate: PPE-fabric

Substance	CAS	Sample			
		23055 23056	23057 23058	23059 23060	23061 23062
1H,1H,2H,2H-Heptadecafluoro-1-decanol	678-39-7	+	+	-	-
2-Phenyl-1,3,2-dioxaborolane	4406-72-8	+	+	-	-
4′-Hydroxy-3′-methylacetophenone	876-02-8	+	+	-	-
Isovanillin	621-59-0	+	+	-	-
Apocynin	498-02-2	+	+	-	-
Acetovanillone	486-25-9	+	+	-	-
9-Methylphenanthrene	883-20-5	+	+	-	-
Methyldehydroabietate	1235-74-1	+	+	-	-
Camphene	79-92-5	-	+[3]	-	-
5-Methyl-1,3-dihydro-2H-benzimidazol-2-one	5400-75-9	-	-	+	+
6-Aminoindolin-2-one	150544-04-0	-	-	+	+

[3]- only detected in sample 23057 (person A)

In some cases only the general substance group could be identified. It was not possible to differentiate individual benzoic acid esters or phthalates.

Alexandra Chukharkina
Responsible for analysis

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

Comments to the first test:

No major differences could be detected between the two methods. However, during the tests the smoke/mist generated during Cobra Save was not ventilated. Because of this both extinguishing methods gave similar exposure to moist and condensed smoke.

There are substances detected in the analysis that only are present in Cobra Save test. These substances are generally quite water-soluble and have a low boiling point. Because of this more individual substances were detected in Cobra Save. The overall composition is still similar between the methods.

During the Cobra Save tests the temperature is on average lower than during standard procedure. The lower temperature might cause substances with a boiling point in the range of 100-400 C to condense instead of staying in the gas phase. In such case, very small droplets of the substance are formed and spread as an aerosol. Such condensation combined with the water mist could create a more efficient scrubbing of these substances from the smoke. The two kinds of fabric used in the tests have different wettability and absorb substances dissolved in water mist to different degrees.

To optimise the Cobra Save procedure the created mist should have been ventilated out of the area before the firefighters enter. Time spent in the room is also connected to exposure and if Cobra Save creates conditions that promote quick work, like lower temperature and better visibility, then results might differ more in reality.

If the mist could be efficiently ventilated it is expected to create a cleaner atmosphere than what could be obtained with standard procedure. The lower temperature during Cobra Save might cause more of the smoke to condense in the water droplets of the mist. This needs to be confirmed with another test.

The detected substances are interpreted as characteristic for fire smoke but are not generally considered safety or health hazards. However, several detected PAH substances are known to pose a risk for health being carcinogenic.
Among other detected substances the benzoic acid esters and phthalates are plastisicers present in synthetic materials and very common in PVC.

Anders Blom
Responsible for analysis

SUSLab
Swedish Unique Solution Laboratory

Analysis report

20240129

Client: Cold Cut Systems AB

Address: P.O. Box 10181
SE-434 22 Kungsbacka, Sweden

Reference: Anders Trewe

Our reference: Anders Blom

Analysis:	Screening of organic substances collected on test patches
Method:	Qualitative analysis, screening using GC-MS for extractable organic substances. Library search using the NIST library with 400 000 substances combined with spectral deconvolution using AMDIS software for verification.
Sample preparation:	Test patches were extracted in ethyl acetate for 72 hours and intermittent shaking. Extraction performed in super-clean glass vials with teflon lid.
Date of analysis:	2023-12-27
Substrate:	According to table
Sample number:	According to table
Performed by:	Anders Blom/Alexandra Chukharkina

Samples

Sample number	Client ID	Substrate	Test	Person #
23088	T0-1B	Cotton fabric	blank	1
23089	T0-2B			2
23090	T1-1B		Cobra Save	1
23091	T1-2B			2
23092	T2-1B		Cobra Save	1
23093	T2-2B			2
23094	T3-1B		Standard	1
23095	T3-2B			2
23096	T4-1B		Standard	1
23097	T4-2B			2
23098	T0-1B	PPE-fabric	blank	1
23099	T0-2B			2
23100	T1-1B		Cobra Save	1
23101	T1-2B			2
23102	T2-1B		Cobra Save	1
23103	T2-2B			2
23104	T3-1B		Standard	1
23105	T3-2B			2
23106	T4-1B		Standard	1
23107	T4-2B			2

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

Results test 2

Substrate: Cotton fabric					
Substance	CAS	Sample			
		23090	23092	23094	23096
		23091	23093	23095	23097
Isovanillin	621-59-0	+[1]			+
p-Cresol	106-44-5			+	
Phenanthrene	85-01-8			+	
2(5H)Furanone	497-23-4				+
Acenaphthene	83-32-9				+
4-Hydroxy-3-methoxyphenylacetone	2503-46-0				+
4-Hydroxy-3-methoxycinnamaldehyde	458-36-6				+
Azumolene	16462-98-9				+
2,6-diisopropylnaphthalene	24157-81-8				+
Fluoranthene	206-44-0				+
Retene	483-65-8				+
Unsaturated aliphatic hydrocarbons			+[1]	+[1]	
Short-chain alcohols			+[1]		
Esters of fatty acids					+

[1]- Only detected in samples from person B

Substrate: PPE-fabric					
Substance	**CAS**	**Sample**			
		23100 23101	23102 23103	23104 23105	23106 23107
p-Toluenesulfonamide	70-55-3	-	-	+[2]	-
o-Toluenesulfonamide	88-19-7	-	-	+[2]	-
Apocynin	498-02-2	-	-	-	+[2]
Coniferyl aldehyd	458-36-6	-	-	-	+[2]
Pyrene	129-00-00	-	-	-	+[2]

[2]- Only detected in samples from person B

In some cases only the general substance group could be identified. It was not possible to diffrentiate individual aliphatics or alcohols.

Alexandra Chukharkina
Responsible for analysis

Denna rapport får endast återges i sin helhet.
Resultaten relaterar endast till de insända proverna.

Comments to the second test:

In this follow-up test the correct procedure of ventilating the area before entering was used for Cobra Save. Apart from this the test conditions were the same, however due to the season the mixture of materials used in the fires had to be changed, no garden furniture was available in the stores.
The results show a difference between Cobra Save and the standard procedure in the amount and nature of detected substance.

Generally, significantly less substances are detected in Cobra Save tests.
The detected compounds in Cobra Save, i.e. short-chain alcohols, are substances with lower boiling point and higher water-solubility, a similar result to the previous test.

In the samples from the standard procedure three known carcinogenic PAH substances were detected: Phenanthrene, Acenaphthene and Fluoranthene, these substances were absent in Cobra Save.

It is not possible to prove if the better performance when using Cobra is due to lower temperature, causing condensation, or due to efficient scrubbing of particles. A combination of both these effects is possible. For example, PAH is known to have a high boiling point as well as high affinity for particles so both effects might be present.

From the users point of view the exact mechanism is of less importance. The result is that using Cobra Save the general amount of detected substances is lower and the PAH substances were not detected at all.

Anders Blom
Responsible for analysis

Conclution

20240312

- When the ventilation is performed using Cobra Save extinguishing procedure, the amount of substances originating from fire smoke and detected on the patches is lower compared to using conventional methods. Also, no carcinogenic PAH from smoke were found in the samples from the Cobra procedure.

- When the ventilation in Cobra procedure is omitted, the total amount of detected contamination is similar between the methods. Prescence of the class of water-soluble substances is higher compared to the standard procedure, possibly due to the combination of different physical factors.

- There is no evaluation of other effects associated with the use of Cobra Save but an efficient scrubbing of soot and particles from the air as well as a lower general temperature are known parameters that in general will decrease exposure of any kind of substance present in the air in the form of droplets or particles. It will also help to improve the working situation by increasing visibility and keeping the temperature under control.

Anders Blom

Responsible for analysis