# Fight Right Decon

StepOne White Paper

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## Introduction

The past 14 years have seen a radical transformation in the fire service as the field has become increasingly aware of the dangers posed to firefighters by exposure to occupational carcinogens. Prompted by the release of IARC (International Agency for Research on Cancer) Monograph #98 on painting, firefighting, and shiftwork in 2010 (1), the fire service has since adopted a number of technologies and operating procedures designed to reduce the severity of carcinogen exposure experienced by line-of-duty firefighters, including wearing SCBAs during overhaul, performing gross decontamination of turnout gear while on scene, using skin wipes and showering to remove soot from the skin after firefighting operations, purchasing second sets of gear, keeping contaminated gear outside of apparatus cabs and living quarters, and installing exhaust-removal systems in apparatus bays. Despite these efforts, though, the share of line-of-duty deaths attributed to cancer has increased from 65% during the years 2002–2021 (2) to 75% in 2022 (3) and 72% in 2023 (4), with the IARC taking the additional step in 2023 of officially classifying firefighting as “carcinogenic to humans,” awarding it their “Group 1” designation for severity, the highest possible (5).

## Exposure routes and carcinogens

Firefighter carcinogen exposure is best analyzed by breaking it down into three exposure routes—respiratory inhalation, dermal absorption, and ingestion—and then examining specific carcinogens associated with each route. A summary of IARC Group 1 carcinogens commonly encountered during firefighting, along with their associated routes of exposure, is presented in **Table 1**.

***Respiratory inhalation:*** Historically, respiratory inhalation has been by far the most severe route of exposure owing to a general lack of respiratory protection available to firefighters, especially due to the nature of fires to produce large quantities of toxic particulates and gasses. Because airborne compounds can be transferred to the lungs without first passing through any physical barrier, inhalation provides an expedient route for nearly any carcinogen to enter the body, including volatile organic compounds and minerals, heavy metals, and non-volatile organic compounds in the form of particulate matter. However, due to the widespread adoption of the SCBA, respiratory exposure is now highly preventable and largely dependent only on the implementation of good policy by departments (6).

***Dermal absorption:*** While respiratory inhalation has been declining as the solely dominant route of exposure, dermal absorption has been dramatically increasing in relevance owning to the large quantity of carcinogenic substances that are deposited on the skin by modern fires, especially those containing synthetic materials commonly used in modern residential construction (7). Fortunately, healthy skin is generally an effective barrier against most carcinogens, including minerals such as asbestos and crystalline silica and volatile organic compounds such as formaldehyde and benzene, but its hydrophobic nature makes it susceptible to absorbing hydrophobic, non-volatile organic compounds such as benzo[a]pyrene and certain lipophilic heavy metals such as arsenic and cadmium (5). Moreover, because skin becomes more absorptive with increasing temperature (8, 9, 10), firefighters are at a unique risk for dermal absorption because their work necessarily couples high ambient temperatures and intense physical exertion with carcinogenic environments. According to the 2015 FAST report, turnout gear is capable of providing substantial protection from these carcinogens owing to its vapor resistance, but because this vapor resistance does not extend to the interfaces between pieces of gear, the neck, forearms, and lower legs are sites of particularly severe exposure (11). Compared to the efficacy of SCBAs to mitigate respiratory inhalation, common measures to mitigate dermal absorption, such as wipes and showers, have much room for improvement, as their use is strictly reactive, and their efficacy is highly dependent on their rapid implementation after exposure, which is not always guaranteed given the dynamic nature of a typical fire scene (12).

***Ingestion:*** Compared to respiratory inhalation and dermal absorption, ingestion is a far less consequential route of exposure and will not be discussed further. It is generally mitigated by implementing good hand-washing practices before eating.

**Table 1 – Summary of firefighting-related Group 1 carcinogens and their associated exposure routes**

| Carcinogen | Category | Exposure routes |
|---|---|---|
| Arsenic | Heavy metal | Respiratory, dermal, oral |
| Asbestos | Mineral | Respiratory, oral |
| Benzene | Volatile organic compound | Respiratory, limited dermal* |
| Benzo[a]pyrene | Non-volatile organic compound | Respiratory, dermal, oral |
| 1,3-butadiene | Volatile organic compound | Respiratory, limited dermal* |
| Cadmium | Heavy metal | Respiratory, dermal, oral |
| Dioxins | Non-volatile organic compound | Respiratory, dermal, oral |
| Formaldehyde | Volatile organic compound | Respiratory, limited dermal* |
| Pentachlorophenol | Non-volatile organic compound | Respiratory, dermal, oral |
| Polychlorinated biphenyls | Non-volatile organic compound | Respiratory, dermal, oral |

Table derived from references (13), (14).

* Volatile organic compounds have limited dermal absorption owing to their rapid evaporation, which removes them from sustained contact with the skin.

## Improving dermal decontamination

To address the present shortcomings of dermal decontamination, Fight Right Decon developed a novel technology that, when paired with conventional wipes and showers, eliminates the weaknesses inherent in these methods that result from their strictly reactive usage and highly time-dependent efficacy. This technology is generally referred to as "decon-boosting gel" and is marketed under the trade name "StepOne." StepOne is the first *proactive* dermal decon product in the fire service.

The core principle of the StepOne technology is to put a thin, sacrificial film on the skin that, upon exposure to carcinogens, will delay their absorption into the skin for long enough that conventional wipes and showers will be able to remove those carcinogens effectively, as depicted in ***Figure 1***. The product itself takes the form of a quick-drying gel that is applied to the skin *one time* at the beginning of the shift and persists for a full 24 hours to provide its absorption-delaying effects at any point during the shift when the firefighter is dermally exposed to carcinogens. Generally speaking, the product should be applied to any exposed skin, but especially to the neck, forearms, and lower legs. Importantly, the face does not need to be treated because it will be protected by an SCBA mask during firefighting.

In terms of the user experience, the product feels like aloe vera gel when it is first applied and dries within a minute to form a thin film that approximates a light, non-greasy sunscreen, but is water-resistant, abrasion-resistant, non-flammable, and hypoallergenic, will not clog pores or interfere with sweating, and can be used without issue in conjunction with any spray-on sunscreen (apply StepOne first, allow it to dry, and then spray on the sunscreen; lotion-based sunscreens are not recommended). The film is easily removable by any type of skin wipe or by any type of body wash, so fire departments who have already implemented the good practices of using skin wipes and taking showers after fires do not need to further modify their decon policies to implement StepOne. It should be noted that, because the nature of the film is to be sacrificial, the product needs to be reapplied after decon is performed.

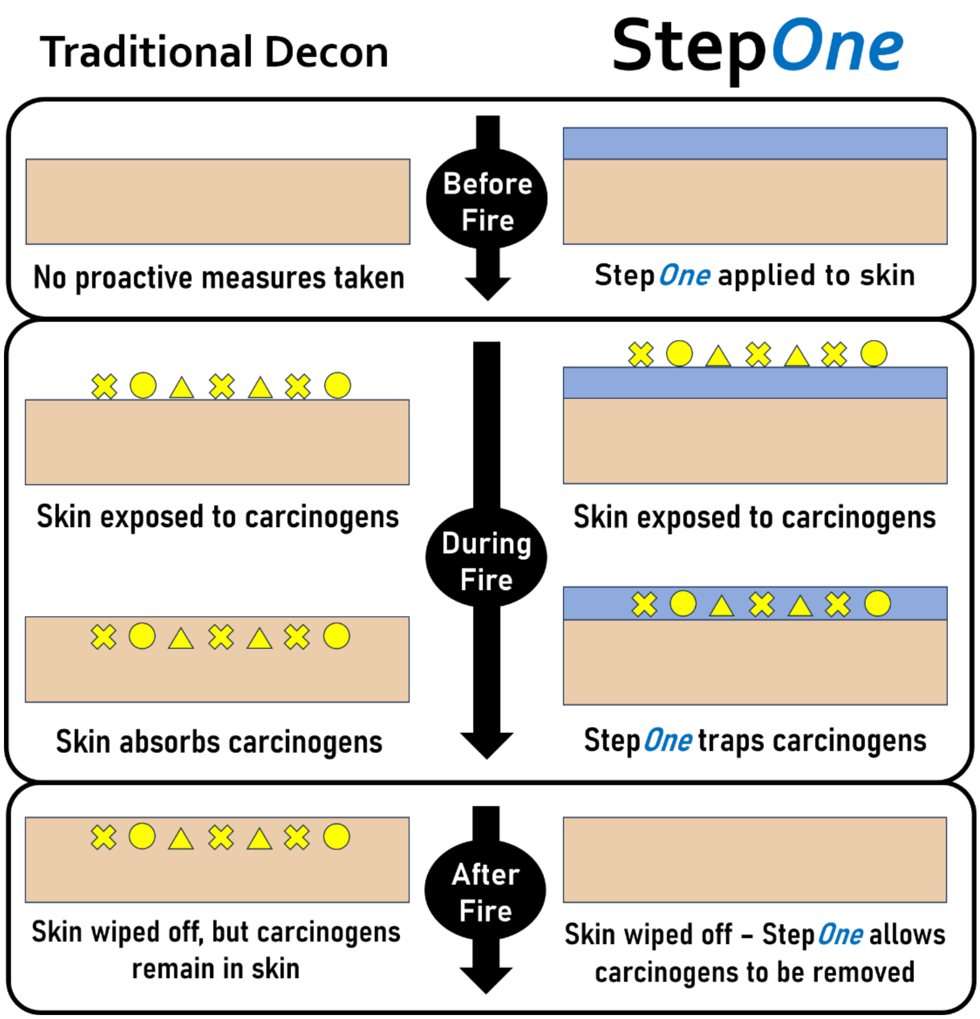


***Figure 1: Simplified working principle of StepOne. "Traditional Decon" refers to the use of skin wipes alone (without StepOne). "StepOne" refers to the use of StepOne followed by skin wipes.***

## StepOne efficacy testing

Efficacy testing was performed on StepOne to characterize its decon performance in conjunction with skin wipes verses the use of wipes alone. Owing to its designation as a Group 1 carcinogen and representative status as a non-volatile hydrophobic compound, benzo[a]pyrene (BaP) was employed as the model carcinogen. To best simulate human skin, an *in vitro* dermal absorption model employing full-thickness porcine ear skin was developed and used for all testing.

Each test began by applying StepOne evenly to a set of skin sections at a coverage level of 5 $mg/cm^2$ (measured after drying), chosen because 5 $mg/cm^2$ was approximately the quantity that an average user was found to apply during routine use. The skin sections were then placed in a humidified incubation chamber warmed to 35°C and allowed to equilibrate for 30 minutes, after which 2 ug of BaP was applied evenly over the surface of each skin section, and simulated firefighting conditions were initiated. Specifically, these conditions involved running a "sawtooth" temperature profile oscillating linearly between 35°C and 42°C with a period of 60 minutes, meant to simulate repeated rotations of 30 minutes of intense interior attack followed by 30 minutes of rehab; these temperature values were chosen because 35°C is approximately average human skin temperature (15) and 42°C is just below the maximum temperature that human skin can continuously tolerate without experiencing thermal injury (16) (these conditions were designed to be strenuous). A large number of tests were run to assess several different exposure durations—1, 2, 4, 8, 16, and 24 hours—and once the exposure duration associated with a given test was complete, the skin sections were removed from the incubation chamber and cleaned thoroughly with individual skin wipes. Methanol was then used to extract the BaP separately from each skin section and its paired wipe, after which the BaP in each extract was quantitated using HPLC-FLD.

The testing apparatus allowed a maximum of 12 identical samples to be run concurrently to assess BaP absorption for a particular exposure duration. For each exposure duration tested, three separate batches of 12 samples each were assessed, producing a maximum of 36 samples for any given condition (some conditions fell short of this number due to a combination of mechanical failures of the apparatus and stringent rejection requirements for bacterial contamination of the skin). All of this was repeated identically to run both a control group and a test group, with the control group omitting the application of StepOne and allowing the skin to be exposed directly to BaP. BaP absorption for any given sample was calculated by dividing the quantity of BaP found sequestered in the skin section by the total amount of BaP detected in both the skin section and wipe that had been used to clean it. For analysis, the use of median and quartiles was the preferred statistical representation due to the high degree of variability inherent to dermal absorption (**Tables 2A, 2B**). Curve fitting was performed according to a power law distribution (**Table 3**), and relative efficacy between the test group and the control group was derived from these curves in order to provide the most accurate assessment for any single exposure duration given the full body of data (**Table 4**). Efficacy multiples were calculated for each exposure duration by dividing the control-group BaP absorption by the test-group BaP absorption. ***Figure 2*** summarizes the BaP absorption data graphically.

 

**Table 2A – Experimental efficacy data for control group**

| | BaP absorption (% of available dose) | | | |
|---|---|---|---|---|
| **Exposure time (hours)** | **Median** | **Quartile 1** | **Quartile 3** | **Sample count** |
| 1 | 7.13 | 4.19 | 10.76 | 32 |
| 2 | 15.38 | 9.31 | 22.90 | 32 |
| 4 | 33.19 | 25.26 | 40.14 | 36 |
| 8 | 37.38 | 28.27 | 47.56 | 30 |
| 16 | 52.23 | 40.97 | 57.07 | 14 |
| 24 | 57.17 | 53.26 | 66.79 | 15 |

**Table 2B – Experimental efficacy data for test group (StepOne)**

| | BaP absorption (% of available dose) | | | |
|---|---|---|---|---|
| **Exposure time (hours)** | **Median** | **Quartile 1** | **Quartile 3** | **Sample count** |
| 1 | 1.62 | 1.16 | 2.42 | 36 |
| 2 | 2.44 | 1.71 | 3.18 | 35 |
| 4 | 2.51 | 1.98 | 3.91 | 35 |
| 8 | 2.72 | 1.61 | 3.82 | 34 |
| 16 | 4.85 | 2.98 | 6.58 | 35 |
| 24 | 4.80 | 4.23 | 7.91 | 32 |

**Table 3 – Fitted curve parameters**

| Power law fit ($y = ax^b$) | | |
|---|---|---|
| | **Control** | **StepOne** |
| $a$ | 0.1354 | 0.0162 |
| $b$ | 0.4708 | 0.3523 |
| $R^2$ | 0.9375 | 0.8999 |

**Table 4 – Fitted curve-derived efficacy data**

| | BaP absorption (% of available dose) | | |
|---|---|---|---|
| **Exposure time (hours)** | **Control** | **StepOne** | **Efficacy multiple** |
| 1 | 13.54 | 1.62 | 8.4 |
| 2 | 18.76 | 2.06 | 9.1 |
| 4 | 26.00 | 2.63 | 9.9 |
| 8 | 36.04 | 3.36 | 10.7 |
| 16 | 49.95 | 4.29 | 11.6 |
| 24 | 60.45 | 4.95 | 12.2 |

 

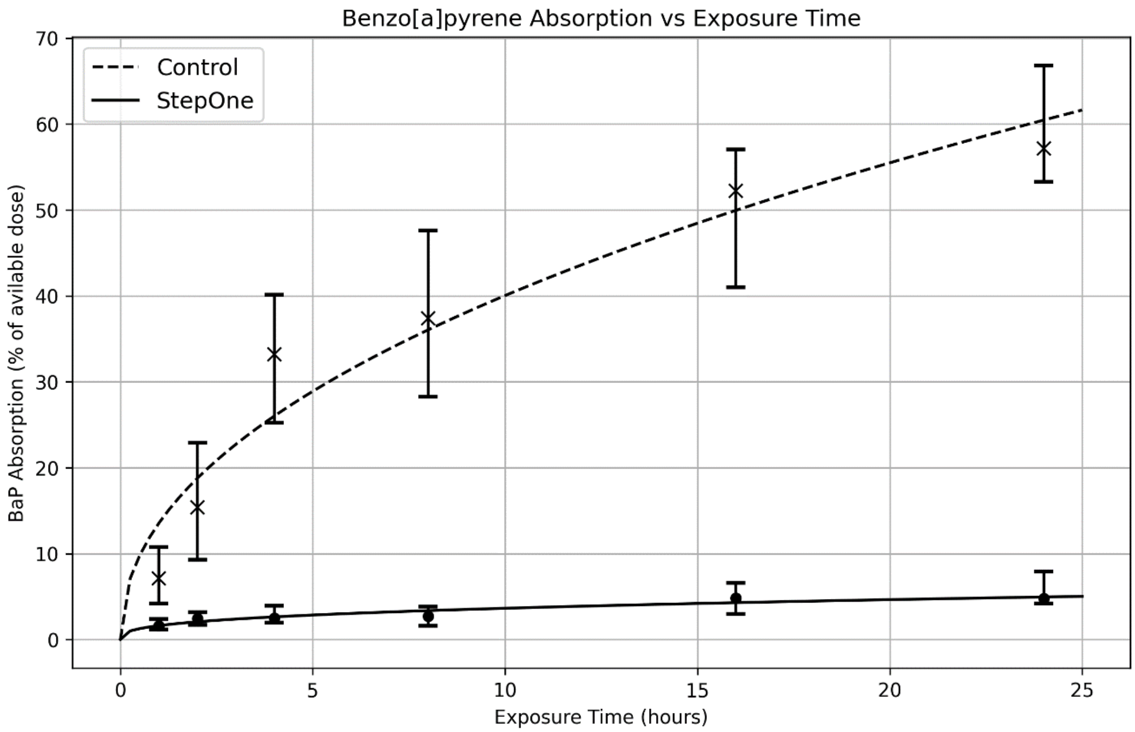


***Figure 2: Graphical summary of efficacy data (benzo[a]pyrene absorption vs exposure time). The graph consists of experimental efficacy data overlayed by fitted curves. Data points indicate the median BaP absorption for the given exposure duration, while positive error bars indicate Q3 and negative error bars indicate Q1.***

## Discussion and Conclusions

The results of efficacy testing show that the use of StepOne in conjunction with skin wipes produces a dramatic increase in dermal decon efficacy verses the use of skin wipes alone, decreasing dermal absorption of BaP by roughly an order of magnitude over all time points tested ranging from 1 to 24 hours (8.4x at 1 hour progressing continuously to 12.2x at 24 hours). The testing also confirmed the deficiencies of relying exclusively on conventional dermal decon methods such as skin wipes, with BaP absorption reaching 13.5% after only 1 hour of exposure and 18.8% after only 2 hours, progressing all the way up to 60.5% after the completion of a 24-hour shift (as assessed by the fitted curve). In comparison, after 24 hours of exposure, skin that was proactively treated with StepOne had absorbed only 4.9% of the available BaP, which is far lower than even 1-hour absorption figures attained though the use of wipes alone.

As affirmed by the data, StepOne represents a dramatic leap forward for dermal decon in the fire service because, for the first time, it enables firefighters to take action against carcinogenic exposures *before* those exposures occur and set themselves up for success to deal effectively with this problem when it arises. Requiring only minimal effort once per shift, necessitating no extra time on the fire ground, being comfortable and easy to apply, and almost entirely eliminating the deficiencies associated with conventional dermal decon methods such as wipes and showers, StepOne is both effective and practical, designed for use in the real world and capable of meeting the unique demands of the modern fire service.

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