

Analysis of levels of 16 different polycyclic aromatic hydrocarbons (PAHs) on contaminated breathing apparatus (harness), breathing masks and helmets before and after pre-treatment and washing in PPE dishwasher with Lejon Kemi cleaning agents and washing programme.



Lejon Kemi

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Background

Soot and combustion gases from fires have been shown to contain many hazardous and carcinogenic substances that can cause serious diseases such as cancer, especially after repeated exposure over a long period of time. The awareness of the health risks posed by exposure to soot and deposits from smoke on breathing apparatus, breathing masks, fire protective clothing, fire hoses and other equipment used by fire service personnel has led to, among other things, a need for new, efficient and safe cleaning methods as well as new, safer working methods and a division of premises into a contaminated side and a clean side.

In recent years, some automated mechanical methods have been developed for cleaning e.g., breathing apparatus and breathing masks, using converted commercial kitchen dishwashers. Initially, short washing times were normal, 6–9 minutes excluding rinsing, using conventional dishwasher detergents. The short washing times and the conventional detergents have not given satisfactory washing results, and in some cases, have led to material damage.



Image 1 and 2. Contaminated and sooty breathing apparatus and parts of the harness. These photos were not taken in connection with sampling but on another occasion.

Breathing apparatus are made up of different kinds of plastics and rubbers, metals and composites. Some parts are painted, lacquered or have other forms of surface treatment. Some of the materials will not withstand cleaning temperatures above 50°C, and some materials cannot withstand cleaning agents found in many conventional detergents. This entails a lot of limitations when it comes to the choice of cleaning substances in the cleaning agents, the choice of cleaning and rinsing water temperatures and flushing pressure when washing breathing apparatus and breathing masks. These limitations, combined with the fact that soot and oil- and fat-soluble tar like contaminants from fires are very difficult to wash away, have made it difficult and time-consuming to develop effective and safe cleaning agents and automated cleaning methods for decontamination of PPE.

New cleaning agents and methods developed by Lejon Kemi

Since the spring of 2011, Lejon Kemi has been developing products and methods for effectively removing hazardous substances and soot from breathing apparatus and other equipment used by fire brigades. The development work has been carried out in consultation and cooperation with various PPE dishwasher and washing machine manufacturers, manufacturers of breathing apparatus, emergency services, external analysis laboratories, chemists and other specialists in a number of different areas.

After research and development work, including full-scale tests at various fire stations over several years, Lejon Kemi can offer effective and safe cleaning agents and cleaning methods (programmes) for decontamination of e.g., breathing apparatus, breathing masks, fire protective clothing, fire hoses and other equipment used by fire brigades.

These new cleaning agents and methods produce highly satisfactory results both visually and according to independent laboratory tests. The cleaning agents and methods are developed and tested to be as gentle as possible on the materials in the equipment and clothing being cleaned. The agents are marketed and sold by Lejon Kemi directly and via retailers in Sweden, Norway, Denmark, Iceland, Slovenia, Germany and the Netherlands. Some of the products are also marketed and sold in several countries by Interspiro, which is part of the Ocenco group. Interspiro are selling the products under their own brands and targets emergency services who use Interspiro breathing apparatus.

Purpose of external analyses of the cleaning effect

It is not possible to visually see or determine the presence of hazardous substances that may be present on surfaces of objects and in textiles exposed to soot and combustion smoke. In light of this, an impartial accredited laboratory was hired by Lejon Kemi to measure levels of 16 different hazardous and carcinogenic polycyclic aromatic hydrocarbons (PAHs) in samples taken from e.g., breathing apparatus, breathing masks, protective helmets, fire protective clothing and fire hoses before and after cleaning. The aim of the analyses was to investigate how effectively the cleaning agent and cleaning method removed PAH in addition to visible dirt and soot. This report states levels of PAH in samples taken from a harness from a breathing apparatus, a breathing mask and a helmet before and after pre-treatment and washing in a PPE dishwasher with Lejon Kemi's cleaning agent and washing programme.

Selection of substances for analysis

The 16 polycyclic aromatic hydrocarbons (PAHs) analysed are normally formed when organic material is burned e.g., during fires in buildings. Polycyclic aromatic hydrocarbons are a group of about 500 substances with two or more benzene rings. Many PAH are harmful to health and include carcinogenic substances like benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene and indeno(123cd)pyrene. Several scientific studies show that exposure to PAH can lead to increased risk of cancer and other health problems, particularly after long and/or repeated exposure. Light PAH compounds are volatile and occur mainly in combustion gases, while heavier PAHs are low-volatility and bind to various materials and airborne soot particles.

Sampling and analysis details

Samples were taken from various surfaces/materials on harness (parts from a breathing apparatus), a breathing mask and a safety helmet which had been contaminated during a smoke diving exercise carried out by the fire brigade in the city of Oskarshamn in Sweden. After pre-treatment and washing in a PPE dishwasher, further samples were taken from the same places as on the contaminated items. The samples were taken by wiping equal-sized surfaces with a special wiping cloth soaked in high-purity ethanol. After sampling, the samples were placed in clean glass containers, which were sealed. After preparation for testing, all samples were analysed by gas chromatography – mass spectrometry (GC-MS).

The cleaning process

Contaminated harness from a breathing apparatus, breathing masks and helmets from Dräger were pre-treated by spraying Lejon Kemi FFE Cleaner in concentrated form onto the items, which were then allowed to soak for three minutes before washing the items in a PPE dishwasher from Wexiödisk. In the test, FFE Cleaner was used, dosed at 2 %, with 20 minutes washing time followed by rinsing with approx. 20 litres of clean water. Wash- and rinse water temperature was 58 - 60°C. After washing, the harness, breathing masks and helmet were allowed to dry completely before samples were taken. Pre-treatment was carried out on the grounds that the items were extremely dirty and sooty after exposure to smoke and soot during a smoke-diving exercise which included the burning of various plastic and rubber objects.

FFE Cleaner is a water-based alkaline detergent, initially developed and optimised for the manual and automated cleaning of e.g., breathing apparatus in so-called PPE dishwashers. The cleaning agent contains various types of surfactants, dispersants, complexing agents and alkali donors. The surfactants, dispersants and complexing agents included in FFE Cleaner are rapidly biodegradable according to OECD criteria.

FFE Cleaner is not suitable for cleaning breathing masks with anti-fog film at temperatures exceeding 50° C manually or in PPE dishwashers. Lejon Kemi generally recommends that breathing masks be washed in a washing machine with Lejon Kemi FPG Wash, where the masks are in protective microfibre washing bags developed by Lejon Kemi and using a washing programme developed for the purpose. Breathing masks that contain electronic components such as built-in communication equipment must not be washed in a washing machine but can be cleaned manually according to the mask manufacturer's instructions.

Method of analysis

Determination of polycyclic aromatic hydrocarbons, PAHs (16 compounds (substances) according to EPA) follows methods based on US EPA 429 and ISO 11338. Measurements were carried out with high-resolution gas chromatography and mass spectrometry (GC-MS), which is an analysis method capable of measuring very low quantities of substances with very high precision.

The analysis laboratory

Sampling and analysis were carried out by ALS Scandinavia AB, Box 700, 182 17 Danderyd, Sweden. Website: www.alsglobal.se Email: info.ta@alsglobal.com Tel: + 46 (0) 8 52 77 52 00 See the attached report T 1822525 from ALS Scandinavia AB.

Analysis results

The analysis results show that it is possible, through pre-treatment and washing in a PPE dishwasher with the cleaning agent and methods developed by Lejon Kemi, to lower the amounts of hazardous and carcinogenic polycyclic aromatic hydrocarbons (PAHs) to very low levels.

On the breathing mask, the total amount of analysed PAHs decreased by 96.4% and the amounts of carcinogenic PAHs was reduced by 92.3 %. On the harness from a breathing apparatus, the amounts of PAHs decreased in total by 87.2 % and the amounts of carcinogenic PAHs decreased by 96.8 %. On protective helmets, the amounts of PAHs were reduced by total of 78.9 % and carcinogenic PAHs decreased by 83.3 %. These analysis results correspond well with results from samples taken during other similar cleaning tests, where heavily contaminated breathing apparatus were pre-treated and then washed in PPE dishwashers with Lejon Kemi's cleaning agent and washing programme.

In several of the samples from cleaned parts, the amounts of individual PAHs were below the detection limit. In cases where the amounts were below the detection limit, the amount for the detection limit has been specified and included in the calculation of the total amounts of PAHs and the amounts of carcinogenic PAHs. This means that the quantities of PAHs can at most amount to the detection limit, 0.05 mg/dm², but may be lower.

According to a visual assessment of the cleaning results after pre-treatment and washing in a PPE dishwasher it was very good, especially considering that the objects used in the cleaning test were very heavily contaminated with soot and dirt after a fire fighter exercise.

It is important to keep in mind that the cleaning result is always dependent on the type and content of the cleaning agent (chemistry), the washing time, the washing temperature, the mechanical processing and the rinsing. This means that the cleaning agent, machine and washing programme form a whole which is decisive for achieving the cleaning result.

Measurement uncertainty

Measurement uncertainty is expressed as an extended uncertainty (according to the definition in Evaluation of measurement data – Guide to the expression of uncertainty in measurement, JCGM 100:2008 Corrected version 2010) calculated with a coverage factor equal to 2, which gives a confidence level of approx. 95%. Measurement uncertainty is only stated for detected substances with levels above the reporting limit (detection limit). Measurement uncertainty from suppliers is normally given as an extended uncertainty calculated with a coverage factor of 2. For further information, please contact Lejon Kemi AB.

Note that samples taken from a specific surface cannot be analysed twice as the sample is destroyed during sample preparation and analysis. Analyses of samples taken on other occasions have shown that the levels of e.g., PAHs can vary widely on contaminated surfaces, even if samples are taken next to each other. This means that the starting levels of samples taken on contaminated objects can vary, which means that even the levels after cleaning can vary, and for this reason, several samples are often analysed to obtain more reliable analysis results.

Individual PAHs before and after pre-treatment and washing in a PPE dishwasher

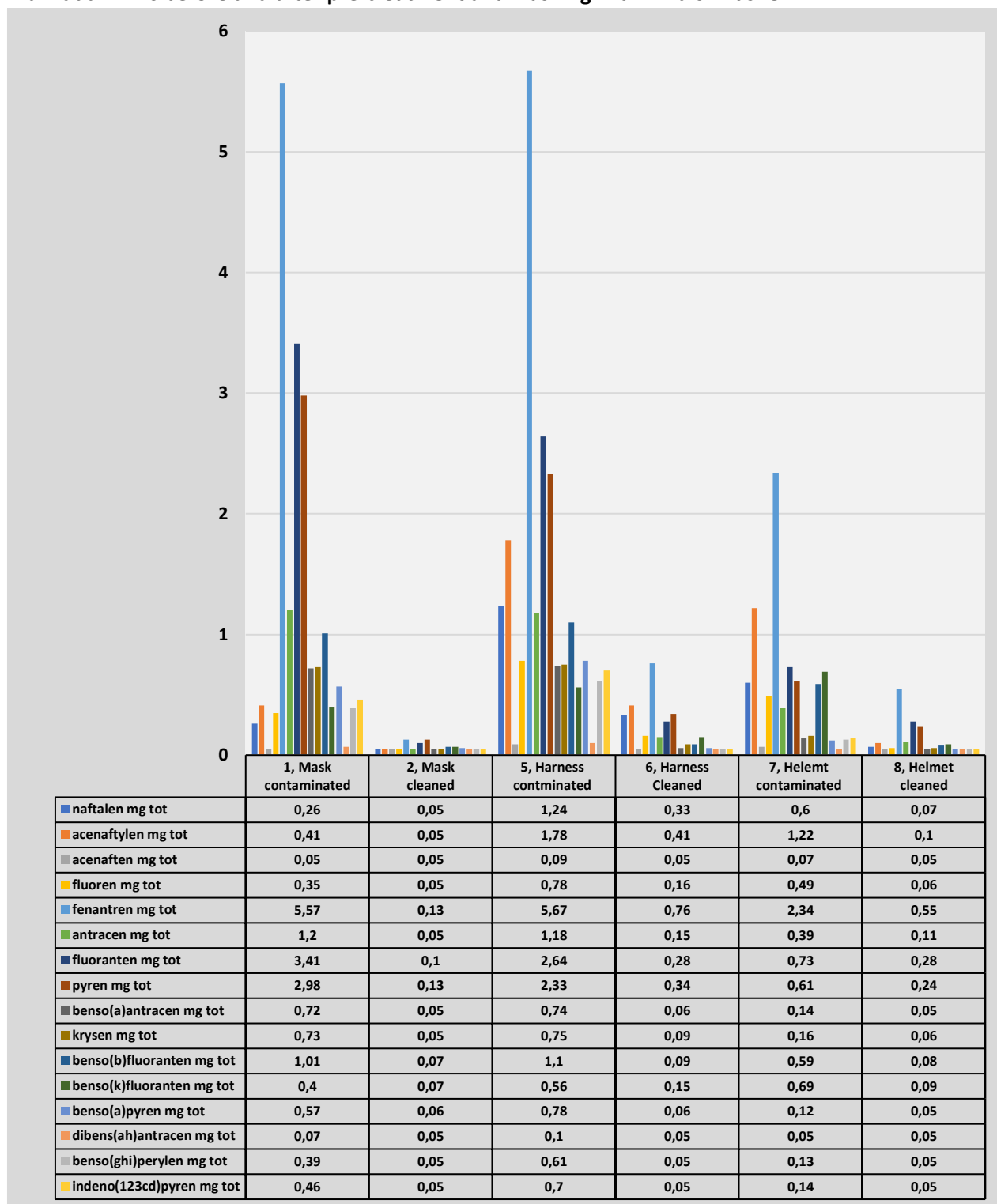


Chart 1. Amounts of 16 analysed polycyclic aromatic hydrocarbons (PAHs) in mg/dm² before and after pre-treatment and washing a breathing mask, harness from a breathing apparatus and helmet in a PPE dishwasher. In cases where the amount of an individual PAHs lies below the detection limit of 0.05 mg, the detection limit has been used in the calculation as it represents the maximum non-detectable amount, such that the amount of the substance could be as much as this maximum without figuring in the analysis. This means that the amounts in mg/dm² can at most be those stated in the Chart, but may be lower. After cleaning, the amounts of PAHs were greatly reduced.

Total levels of PAHs before and after pre-treatment and washing in a PPE dishwasher

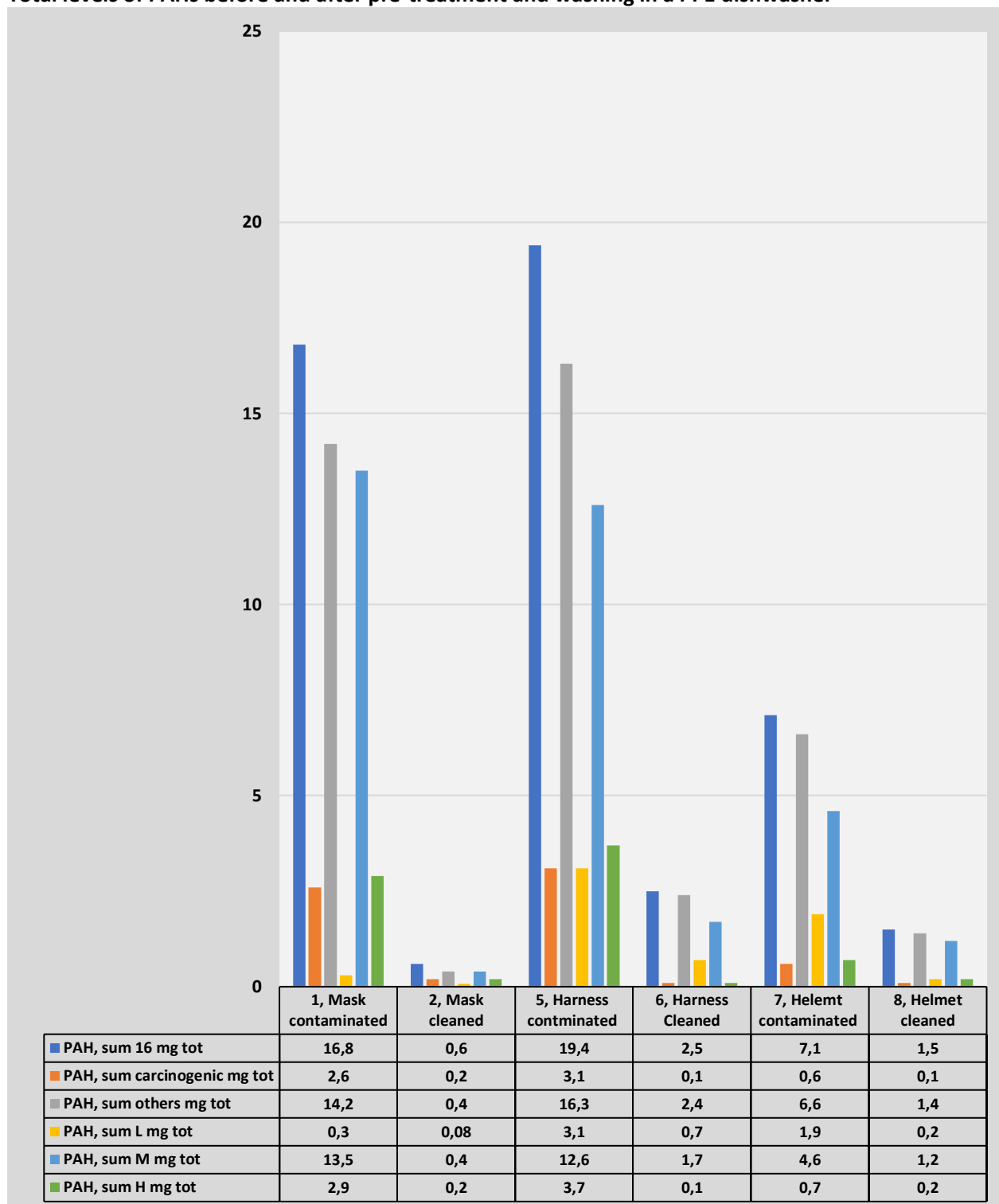


Chart 2. Total levels in mg/dm² of 16 analysed polycyclic aromatic hydrocarbons (PAHs) before and after washing a breathing mask, back protector and helmet in a PPE dishwasher. In cases where the quantity of an individual PAHs per dm² was below the detection limit, the detection limit has been included in the summary because the detection limit indicates the highest possible amount that cannot be detected. The quantity of the individual analysed PAHs per dm² can be at most the detection limit but may be lower. After cleaning, the levels of PAHs were greatly reduced. The total amount of analysed PAHs decreased on average by 87.5 % and the amounts of carcinogenic PAHs decreased by an average of 90.8 %.

PAHs on breathing mask before and after pre-treatment and washing in a PPE dishwasher.

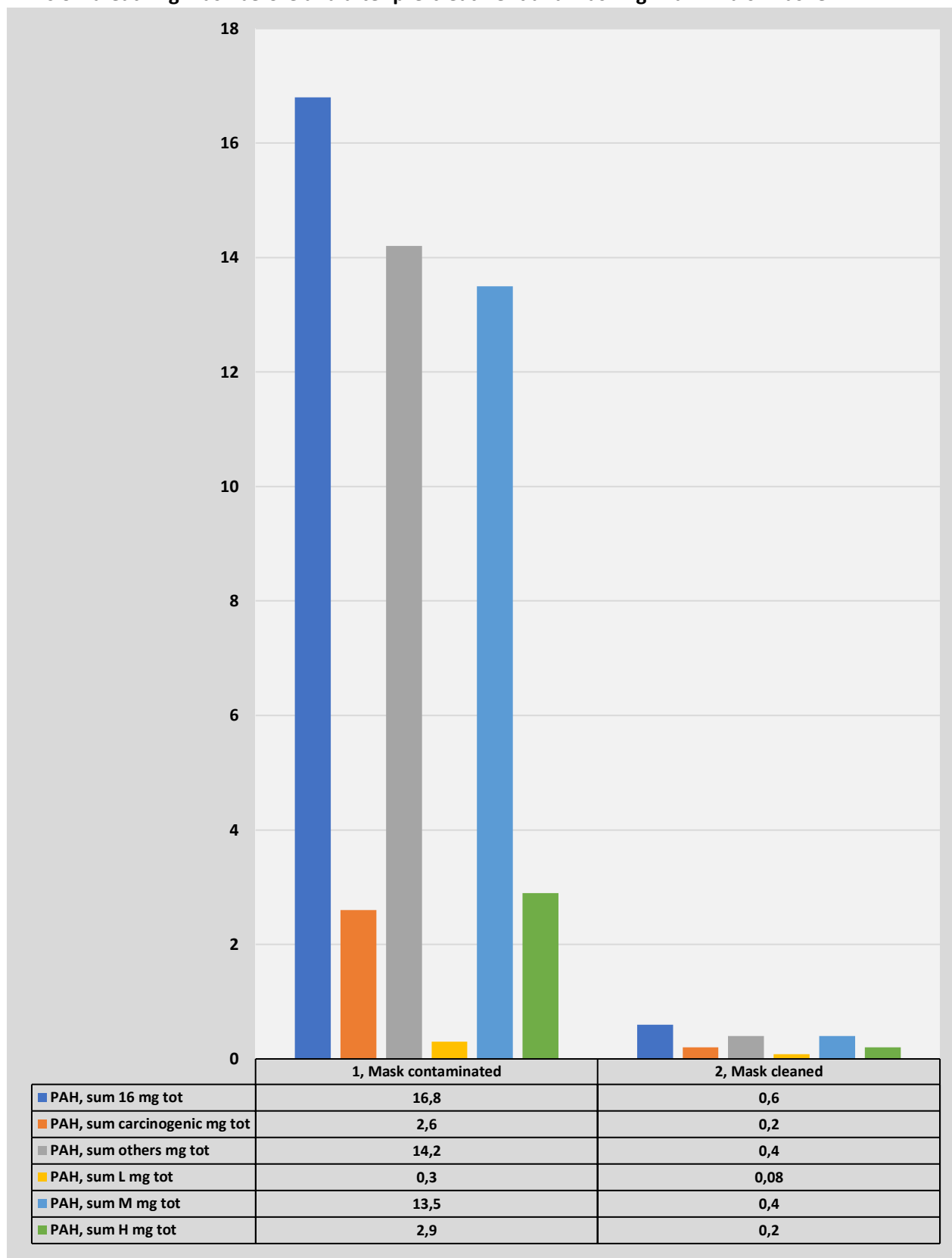


Chart 3. Total amounts of 16 different PAHs in mg/dm² on a contaminated breathing mask before and after pre-treatment and washing in a PPE dishwasher. The total amounts of analysed PAHs decreased by 96.4% and the amounts of carcinogenic PAHs decreased by 92.3% to very low levels after washing. Levels of 9 individual PAHs were after cleaning below the detection level.

PAHs on harness before and after pre-treatment and washing in a PPE dishwasher.

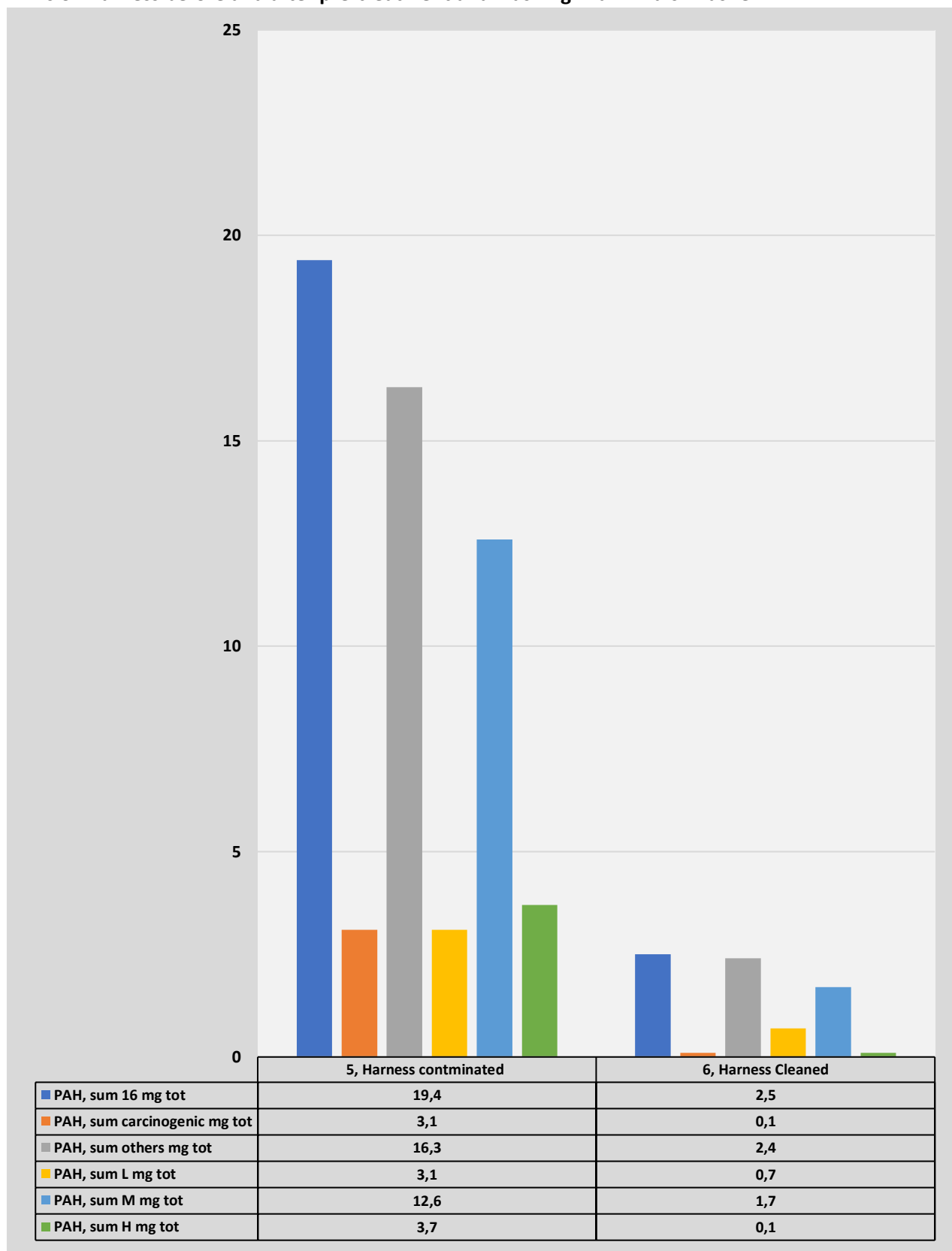


Chart 4. Total amounts of 16 different PAHs mg/dm² on a contaminated harness before and after pre-treatment and washing in a PPE dishwasher. The total amounts of analysed PAHs decreased by 87.1 % and the amounts of carcinogenic PAHs decreased by 96.8% to very low levels after washing. Levels of 8 individual PAHs were after cleaning below the detection level.

PAHs on helmet before and after pre-treatment and washing in a PPE dishwasher

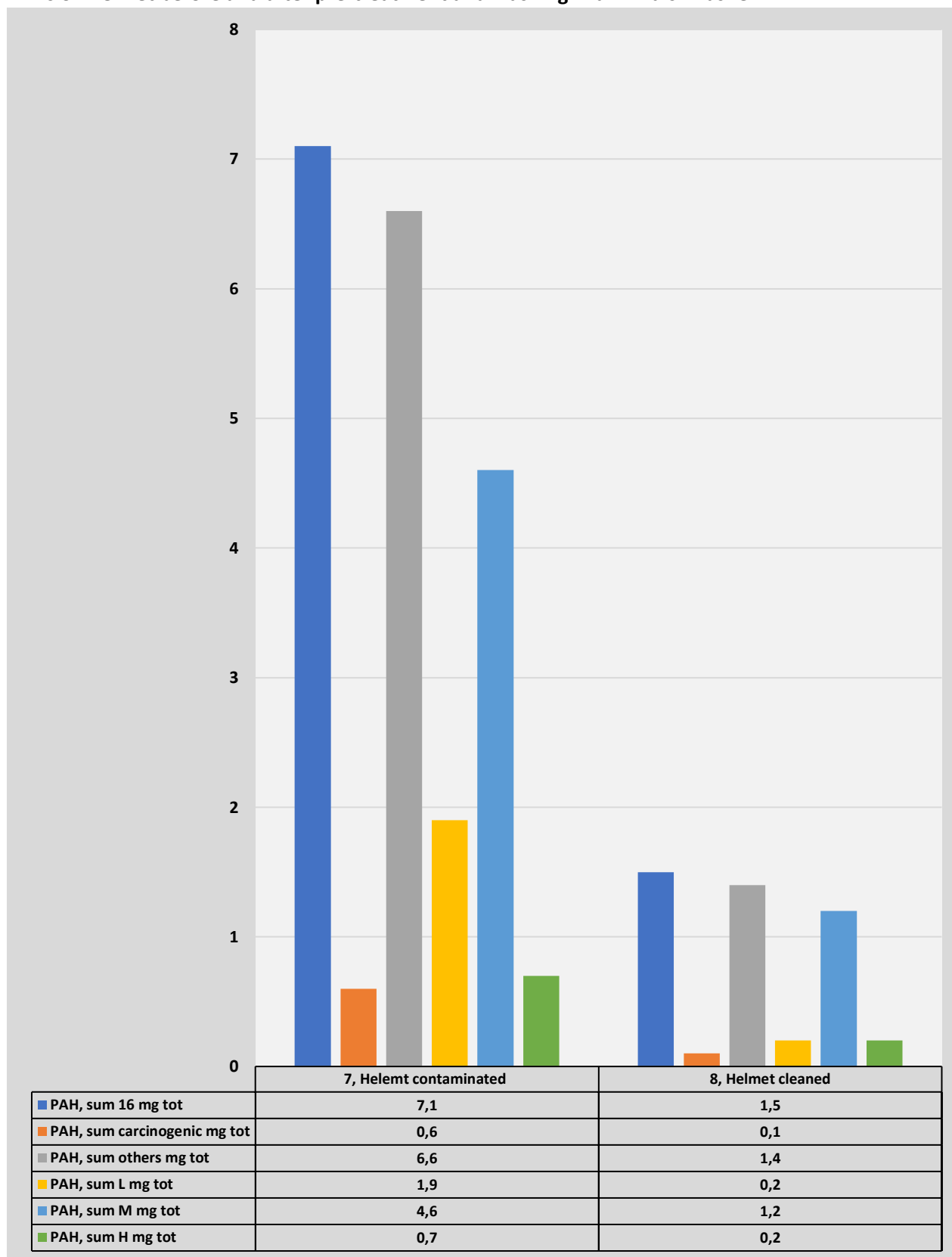


Chart 5. Total amounts of 16 different PAHs mg/dm² on a contaminated helmet before and after pre-treatment and washing in a PPE dishwasher. The total amounts of analysed PAHs decreased by 78.9% and the amounts of carcinogenic PAHs decreased by 83.3% to very low levels after washing. Levels of 7 individual PAHs were under the detection level after cleaning.

Results after pre-treatment and washing in a PPE dishwasher



Image 3. Air cylinder and carrying strap after pre-treatment with concentrated FFE Cleaner followed by washing in a PPE dishwasher at 60 °C for 20 minutes with 2 % FFE Cleaner. The cleaning result was excellent according to visual assessment and according to analyses of 16 different PAHs before and after cleaning.

Summary

By pre-treating and washing in PPE dishwashers of breathing apparatus, breathing masks and helmets it is possible to achieve excellent cleaning results with Lejon Kemi FFE Cleaner (cleaning agent) in combination with pre-treatment methods and washing programmes developed by Lejon Kemi.

Breathing mask

Total amounts PAHs decreased by 96.4% and the amounts of carcinogenic PAHs decreased by 92.3%. Levels of 9 individual PAHs were after cleaning below the detection level.

Harness to a breathing apparatus

Total amounts PAHs decreased by 87.1 % and the amounts of carcinogenic PAHs decreased by 96.8%. Levels of 8 individual PAHs were after cleaning below the detection level.

Helmet

Total amounts PAHs decreased by 78.9% and the amounts of carcinogenic PAHs decreased by 83.3%. Levels of 7 individual PAHs were under the detection level after cleaning.

The above results correspond well with other analysis results done after similar cleaning tests on breathing apparatus and breathing masks at other fire brigades in Sweden.

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