Analysis of hazardous and carcinogenic polycyclic aromatic hydrocarbons (PAHs) on contaminated fire hoses before and after washing with Lejon Kemi Hose Cleaning Agent and washing recommendations

Lejon Kemi

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Background

Soot from fires has 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. Awareness of the health risks associated with exposure to soot and substances in combustion gases has led to a range of protective measures. Examples of such measures include the division of premises into a contaminated side and a clean side, new, safer working methods and new, efficient and safe methods for washing and cleaning e.g. breathing apparatus, breathing masks, fire protective clothing, fire hoses and other equipment used by fire service personnel.

Soot and many of the hazardous substances in combustion smoke and in soot are oil and fat soluble and some have a tar-like consistency with good adhesion to many materials. This makes them difficult to wash off from certain types of plastics, rubber, painted and lacquered surfaces and certain types of synthetic textiles. In order to achieve the best possible results, it is extremely important that all parameters that affect the results, such as type and content of cleaning agents (chemistry), cleaning temperatures, time and mechanical treatment and rinsing, are optimised as far as possible, without damaging the materials of the equipment or protective clothing being cleaned.

New cleaning agents and methods developed by Lejon Kemi

Since the spring of 2011, Lejon Kemi has been developing cleaning agents and cleaning methods to effectively remove soot and hazardous substances from breathing apparatus, breathing masks, firefighter suits, fire hoses and other equipment used by fire services. The development work has been carried out in consultation and cooperation with various PPE spray washer and immersion washer manufacturers, manufacturers of breathing apparatus, emergency services, external analysis laboratories, chemists and other specialists in a number of different areas.

After several years of research, extensive laboratory work and comprehensive full-scale tests at various fire stations, in January 2018, Lejon Kemi was able to offer emergency services a series of cleaning agents as well as washing programmes for cleaning different types of equipment and protective clothing.
Lejon Kemi's product programme includes cleaning agents and specially developed methods for washing breathing apparatus in PPE spray washers (PPE dishwashers), for washing breathing masks and firefighter suits in washing machines and for soaking and washing fire hoses.

The new cleaning agents and cleaning methods (washing programmes) provide excellent cleaning results both visually and according to independent laboratory analyses. The cleaning agents and methods are developed and tested to be as gentle as possible on the materials in equipment and protective clothing and fire hoses being cleaned. Material impact tests have often been carried out in consultation and in collaboration with various manufacturers of e.g. breathing apparatus, protective clothing, fire hoses and with emergency services. Lejon Kemi's products are marketed under our own brands via dealers in Sweden, Norway, Denmark, Iceland, Slovenia, Germany, the UK and the Netherlands and are used by hundreds of fire services. Some of the products are sold by Interspiro, which is part of the Ocenco Group, under Interspiro's own brands. Interspiro markets and sells the products in several countries and targets primarily emergency services that use Interspiro's breathing apparatus and breathing masks.

Purpose of external analyses of the cleaning effect when washing fire hoses

It is very difficult, if not impossible, to see or to determine visually whether hazardous substances are present on surfaces which have been exposed to smoke and gases from fire. Against this background, an impartial certified laboratory was commissioned by Lejon Kemi to measure the level of a number of hazardous substances, polycyclic aromatic hydrocarbons (PAHs), in samples taken from highly contaminated fire hoses before and after cleaning. The purpose of the analyses has been to investigate how effective Lejon Kemi's hose cleaner is in combination with given washing recommendations. Until now, fire hoses have generally been soaked in cold water in tubs without added cleaning agents before washing in a hose washer. However, this method has not provided satisfactory cleaning results, and in light of this, Lejon Kemi has developed a hose cleaning agent as well as recommendations for soaking and washing to achieve more effective cleaning.

Soaking and washing fire hoses before analysis

A fire hose heavily contaminated with soot was soaked for 15 hours in a water bath with an initial temperature of about 60° C and 3 % of Lejon Kemi's hose cleaner. After soaking, the fire hose was washed in a Werma hose washer, model HM 200. In the machine, the outside of the hose was brushed and flushed with water at 160 bar pressure. After washing, the hose was pressure-tested and dried before being sampled for analysis and coiled up. Samples were also taken for analysis after soaking in cold water (10–15 °C) for 15 hours, and without the addition of a cleaning agent, before washing in a hose washer with brushes and high-pressure flushing.

Image 1. Soaking tubs for fire hoses and machine for washing fire hoses, pressure testing, drying and coiling.

Sampling and analysis details

Samples for analysis were taken from a new, unused fire hose, from a used fire hose heavily contaminated with soot and from a fire hose soaked at 60° C with the addition of 3 % Lejon Kemi Hose Cleaning Agent before washing. Samples were also taken from a hose soaked in cold water (10–15° C) without adding a cleaning agent before washing.

After preparing samples and extracting e.g. oil- and fat-soluble substances, a number of samples were analysed by an independent accredited laboratories, like ALS Scandinavia AB, Danderyd Sweden, with gas chromatography – mass spectrometry with respect to 16 different polycyclic aromatic hydrocarbons (PAHs).

Selection of substances for analysis

The 16 polycyclic aromatic hydrocarbons analysed are normally formed when organic material is burned e.g. during fires in buildings. Polycyclic aromatic hydrocarbons are a group of substances with two or more benzene rings. PAHs make up a total of some 500 substances which are more or less harmful to health, and several types are carcinogenic, such as 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 cancers and other health problems, particularly after long and/or repeated exposure.

Lighter PAH compounds are volatile and occur mainly in combustion gases, while heavier PAHs are low-volatility and bind more easily to various materials and airborne particles such as soot. The particles can in turn end up on various types of equipment and fire protection clothing used by fire service personnel. This means that exposure to PAH can happen through inhalation, skin contact or ingestion.

Methods 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.

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. 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.

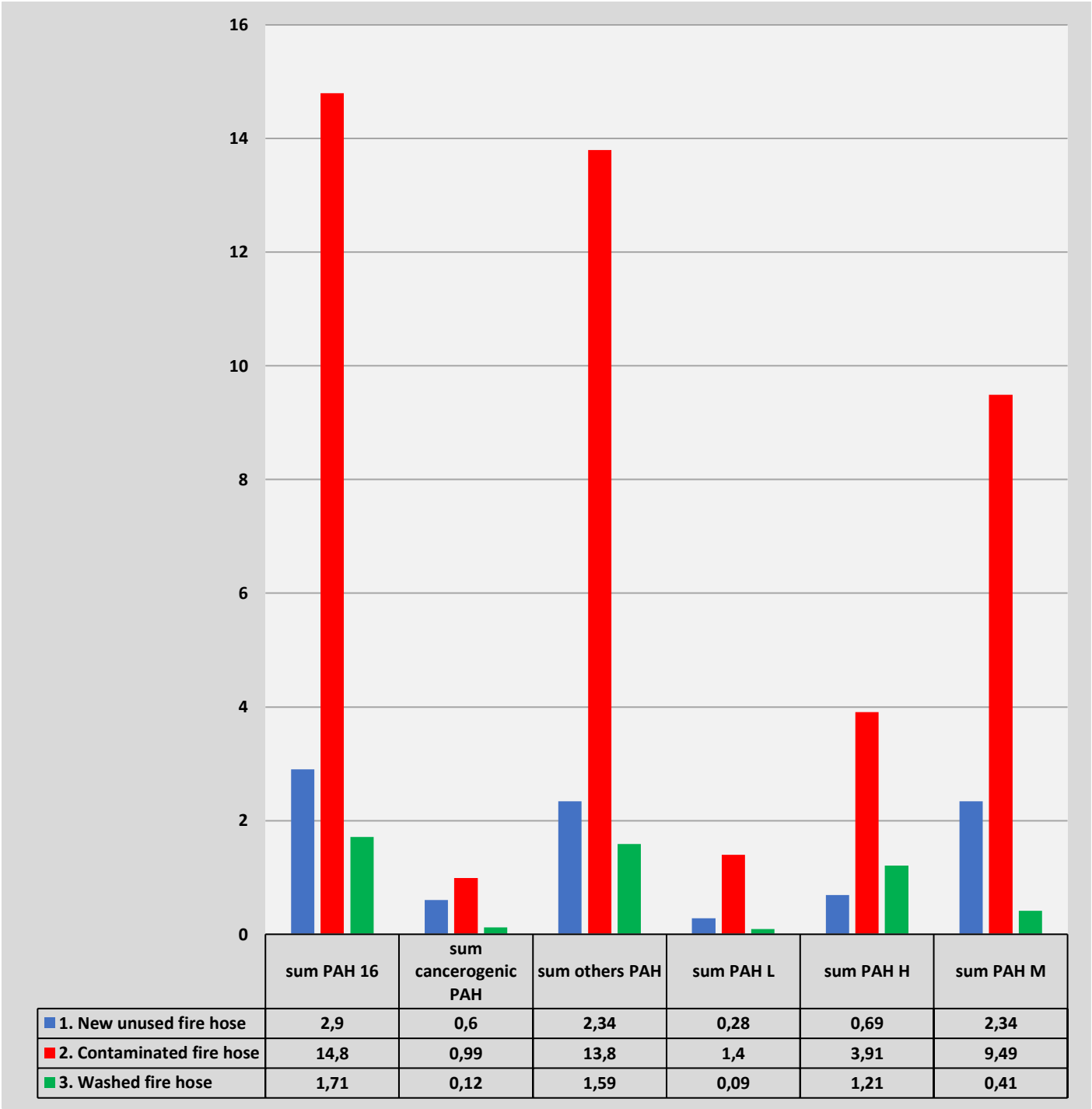
Levels of certain types of PAH on a new, unused fire hose and on a fire hose soaked in a water bath at 60 °C, with the addition of a cleaning agent before washing in a hose washer, were below the detection level limit for the analysis method. In these cases, the value for the detection level has been used in the compilation of source material. This means that the levels of these PAHs can at most reach the detection level but can be lower.

NOTE! It is not possible to analyse exactly the same sample twice, as the levels of e.g. PAHs can vary widely between different contaminated samples – even if they are taken from the same objects, right next to each other. This means that the levels can vary somewhat from sample to sample after washing. For this reason, several samples from the same object are often analysed to obtain a more reliable average value.

Analysis results

The results from the analyses show that the total PAH levels after soaking at 60° C and washing decreased by 88.5 % and that the levels of carcinogenic PAH decreased by 87.9 % compared to the levels in samples taken from the contaminated fire hose before cleaning. In samples analysed after soaking in cold water (10–15° C), without the addition of a cleaning agent before washing in a hose washer, the PAH levels decreased significantly less. The total PAH content was reduced by only 36.5% and the carcinogenic PAH content by 37.4%. **See Charts 1 and 2 below**.

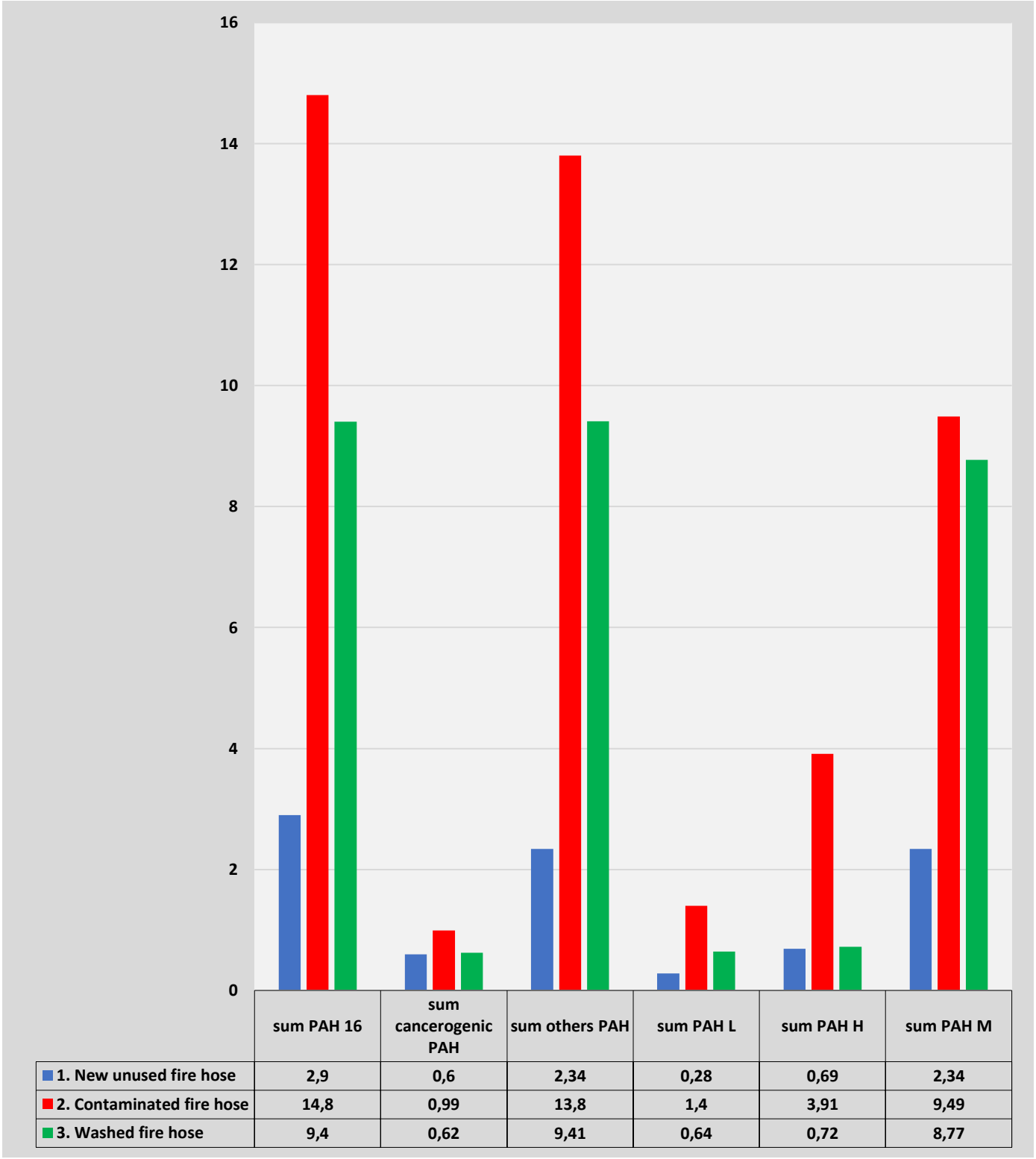
PAH levels on a fire hose soaked in hot water with Lejon Kemi Hose Cleaning Agent



	sum PAH 16	sum cancerogenic PAH	sum others PAH	sum PAH L	sum PAH H	sum PAH M
1. New unused fire hose	2,9	0,6	2,34	0,28	0,69	2,34
2. Contaminated fire hose	14,8	0,99	13,8	1,4	3,91	9,49
3. Washed fire hose	1,71	0,12	1,59	0,09	1,21	0,41

Chart 1. Total levels in micrograms/grams of 16 different polycyclic aromatic hydrocarbons (PAHs) on a new, unused fire hose, a fire hose contaminated with soot and on a fire hose soaked in a water bath at starting temperature of approx. 60 °C with 3% Lejon Kemi Hose Cleaning Agent and which was then washed in a hose washer with high-pressure flushing at 160 bar. Results: The total content of analysed PAH decreased by 88.5 % and the content of analysed carcinogenic PAH by 87.9 %.

PAH levels on a fire hose soaked in cold water without added cleaning agent.



	sum PAH 16	sum cancerogenic PAH	sum others PAH	sum PAH L	sum PAH H	sum PAH M
1. New unused fire hose	2,9	0,6	2,34	0,28	0,69	2,34
2. Contaminated fire hose	14,8	0,99	13,8	1,4	3,91	9,49
3. Washed fire hose	9,4	0,62	9,41	0,64	0,72	8,77

Chart 2. Total levels in micrograms/grams of 16 different polycyclic aromatic hydrocarbons (PAHs) on a new, unused fire hose, a fire hose contaminated with soot and on a fire hose soaked in a cold water bath of approx. 12 °C – 15 °C for 12 hours, without a cleaning agent, and then washed in a hose washer with high-pressure flushing at 160 bar. Results: The total content of analysed PAH decreased by 36.5% and the content of analysed carcinogenic PAH by 37.4%.

Based on both a visual assessment and on analyses of PAH, it appears that the cleaning result is considerably better if fire hoses are soaked in hot water (max. 60° C), with the addition of a cleaning agent developed for the purpose before washing in a hose washer, compared to fire hoses that are soaked in cold water without the addition of a cleaning agent before washing in a hose washer.

Fire hose contaminated with soot before and after soaking and washing

Image 2. Top: contaminated fire hose. Bottom: fire hose soaked at 60 °C with 3% Lejon Kemi Hose Cleaning Agent for 15 hours and washed in a hose washer with brushes and high-pressure flushing at 160 bar.

Image 3. Used fire hose, heavily contaminated with soot

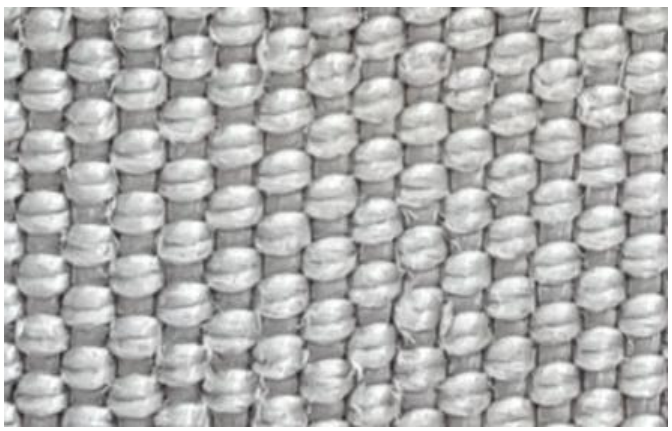


Image 4. Fire hose from Image 3 after soaking and washing.

The images above show a used fire hose, very heavily contaminated with soot before washing and after soaking at 60° C with 3 % of Lejon Kemi Hose Cleaning Agent for 15 hours before washing in a hose washer, model Werma HM 220, with high pressure flushing at 160 bar. Virtually all visible dirt and soot were removed in the washing process.

Tests performed by soaking and washing fire hoses with a rubber jacket

Lejon Kemi and its distributors have carried out tests at fire stations in Norway, cleaning fire hoses with a rubber jacket contaminated with soot. Fire hoses with a rubber jacket are common at fire stations in Norway and several other countries.

During these tests, fire hoses contaminated with soot were soaked partly in warm water (40° C) with 1 % Lejon Kemi Hose Cleaning Agent for four hours and partly in cold water (10–15° C) without the addition of a cleaning agent, after which they were run through a hose washer with brushes and water flushing.

Washing procedure with soaking in warm water and 1 % Lejon Kemi Hose Cleaning Agent

A yellow, rubberised fire hose contaminated with soot, made by Mandals and used for five years, was soaked for four hours in a tub of initially warm water at about 40° C with the addition of 1 % Lejon Kemi Hose Cleaning Agent. After soaking, the hose was run through a hose washer with brushes but without water flushing and then once more but with water flushing switched on.

Cleaning effect

Cleanliness was assessed visually by comparing the contaminated hose before and after cleaning. Photos were taken to document the results on the fire hose contaminated with soot before soaking and washing and after soaking and washing. The cleaning result was very good, without visible residues of soot and other dirt. **See Images 5 and 6 below.**

Image 5. Contaminated 5-year-old fire hose

Image 6. Fire hose from Image 5 after soaking and washing.

Washing procedure with soaking in cold water and 1 % Lejon Kemi Hose Cleaning Agent

A used, red rubber fire hose very heavily contaminated with soot from the Oslo Fire Service was soaked in a tub of cold water 10–15° C with the addition of 1 % Lejon Kemi Hose Cleaning Agent for 12 hours. After soaking, the hose was run through a hose washer with brushes and water flushing.

Cleaning effect

Cleanliness was assessed visually by comparing the contaminated hose before and after cleaning. Photos were taken to document the results on the fire hose contaminated with soot before soaking and washing and after soaking and washing. The cleaning result was judged to be good, with only a few small grey to black discolorations on the hose. **See Images 7 and 8 below.**

Image 7. Very heavily soiled and sooty fire hose with rubber jacket before soaking and washing.

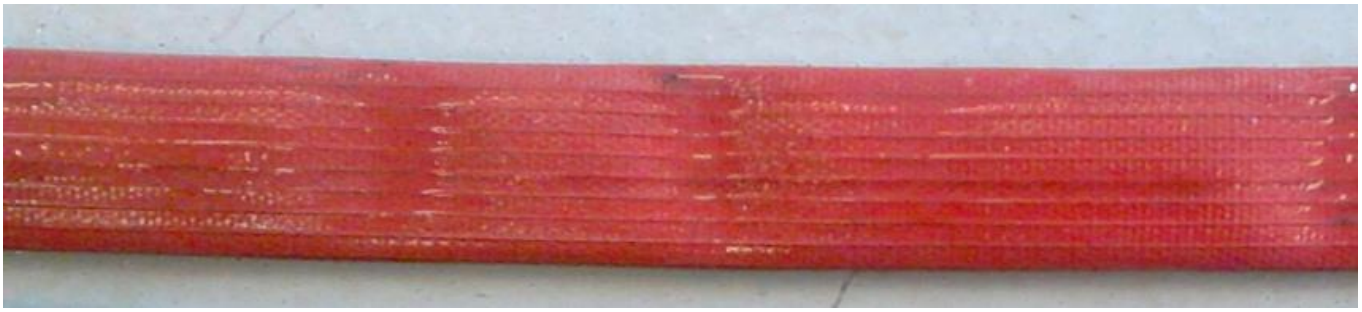


Image 8. Fire hose with rubber jacket from Image 7 after soaking for four hours in water at 40 °C with 1% Lejon Kemi Hose Cleaning Agent and then washed in a hose washer with brushes and water flushing.

Cleaning effect on fire hose soaked in cold water without added cleaning agent

Cleanliness was assessed visually after soaking in cold (10–15° C) water for 24 hours without the addition of a cleaning agent, followed by washing in a hose washer with brushes and water flushing. A lot of soot and other greasy dirt remained on the fire hose after washing. **See Image 9 below**.

Image 9. Contaminated fire hose with rubber jacket after soaking in cold water (10–15° C) for 24 hours without added cleaning agent and then washed in a hose washer with brushes and water flushing.

Lejon Kemi Hose Cleaning Agent

Lejon Kemi Hose Cleaning Agent is an alkaline, water-based detergent specially developed for soaking fire hoses prior to washing in a hose washer. The agent effectively loosens soot, oil, grease and other hard-to-remove contamination from plastic, rubber, metals (e.g. stainless steel, aluminium, brass), painted and lacquered surfaces without damaging the materials in the fire hose or hose couplings. The hose cleaning agent is composed of alkali donors as well as several different types of surfactants, dispersants and complexing agents that are rapidly biodegradable according to OECD criteria (301A-301F). The surfactants are mainly based on renewable, plant-based materials. The packaging is made from polyethylene/polypropylene and can be recycled by sorting as hard plastic packaging or incinerated for energy recovery.

Summary

The results of the analyses show that it is possible to achieve excellent cleaning results and reduce PAH levels to very low levels on contaminated fire hoses by first soaking them in hot water (max 60° C) with the addition of Lejon Kemi Hose Cleaning Agent and then washing them in a hose washer with brushes and water flushing (high pressure flushing, 160 bar), in accordance with the method described in this report. **See Chart 1.**

Soaking in cold water without the addition of a cleaning agent, followed by washing in a hose washer produces a significantly worse cleaning result, especially on fire hoses with a textile jacket. **See Chart 2.**

Fire hoses with a rubber jacket seem to be easier to clean as the outer surface is significantly smoother than fire hoses with a textile jacket. Fire hoses with a rubber jacket have a smooth outer surface, which means that soot particles and other dirt do not stick as easily as on fire hoses with a textile jacket.

In order to achieve a good cleaning result, and minimise levels of health-hazardous substances, it is advisable to use warm water (max 60° C) to soak the hoses as well as a cleaning agent developed for the purpose, such as Lejon Kemi Hose Cleaning Agent, before washing in a hose washer. If hot water can also be used in the hose washer when rinsing the hoses, the cleaning result can be further improved. Processing with brushes and/or high-pressure flushing in a hose washer is important for the cleaning result.

Use of hot water for soaking and washing significantly improves cleaning results. Oil- and fat-soluble contaminants become thinner in warm water and thus easier to wash away. It is also important to change the cleaning bath for each new set of fire hoses to be washed, partly to optimise the cleaning result and partly to prevent the growth of bacteria and other microorganisms in the bath and on the fire hoses.

Cleaning result = Type and content of cleaning agent (chemistry) + temperature + time + mechanical processing + rinsing

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