Application of aerosol extinguishing agents to increase infrastructure safety

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Abstract. Fire protection of buildings, their sets and in the broader concept of the hole built-up and state undeveloped territory is one of the basic conditions of any advanced human society. The current scientific knowledge of extinguishing agent different types allows more fires to be managed adequately and effectively. Aerosol fire extinguishers belong to relatively newly developed methods of fire protection connected with buildings and technical infrastructure. By their nature, properties, effects and ecologically sound, this technology has received much attention from the gradual phasing out and reduction of halogen extinguishing agents since the early 1980s, due to the Montreal Convention. Very surprising results and improvement were reached due to modern carbon nanocomposites such as graphene oxide, fullerene and its modifications which were not intended to be used in such fields at all. But thanks to their in-depth examination and advanced technology their exploitation seem to be unlimited.

1. Introduction
With the upcoming climate change and the already periodically occurring meteorological and accompanying hydrological drought, an increase in the fire numbers in built-up areas can be expected almost confidently but also the undeveloped territories of the state. For fires in temperate and subtropical zones for natural causes or anthropogenic events, they will tend to affect all infrastructure elements in the number of local areas of the given regions with minimal rainfall. For this emerging situation, the regional public administration has to be sufficiently prepared with a sufficient extinguishing potential. In practice the wide range of extinguishing agents is used in practice, depending on the type of fire, the environment in which it originated and the optimum means by which means and methods can eliminate the consequent material damage to the maximum extent possible. In practice, water is the most important and most frequently used extinguishing agent. However, many fires cannot be extinguished with water. To extinguish fire, it is necessary to use other types of extinguishing agent that eliminate or at least minimize the danger to life and health of the intervention units and at the same time reduce secondary damage caused by fire intervention.
In the terms of technical infrastructure, technological, machine and production units, aerosol fire extinguishing agents are among the most important and with good prospects for further development and aerosol usage.

2. Current state of solved problems
With the new scientific knowledge of matter and its composition, the knowledge about the possibility of using various properties of these substances for fire-fighting purposes gradually developed. Since the second half of last century these new substances supplemented the list of substances that can be used to extinguish various types of fires with the advantage or necessity. In terms of classification of extinguishing agents and extinguishing equipment, they can be divided into the following groups:

• sources of fire-fighting substances of natural origin,
• multipurpose and artificial sources and means of extinguishing media,
• chemical extinguishing agents of chemical origin [1].

Each of the above groups has its specific extinguishing effects and can be used for different types of fires. Some types of extinguishing agents can be combined with others, while others need to be followed when selecting.

2.1. Aerosol extinguishing agent problems

The principle of extinguishing aerosol devices is based on the formation of extinguishing aerosol. At the fire point, there is a reaction that converts a solid aerosol-forming mixture by burning out, we can also speak about pyrotechnic composition into very small particles consisting of both microscopic and submicroscopic matter particles which largely eliminate the fire based on chemical extinguishing mechanism principles with its anti-catalytic and inhibitory effect. To some extent we can talk about partial similarity with extinguishing powders but the extinguishing aerosols effectiveness is several times higher (reported 8-14 times compared to extinguishing powders).

This multiple efficiency is mainly due to the size of released particles, again compared to extinguishing powders, the values are 10-100 times lower, and very low aerosol sedimentation rate which is able to hold in the air for tens of minutes depending on environmental conditions to which it was applied. The smaller particles, the large they are able to create an active surface on which contact with the fire radicals itself and mutual collision [2].

Aerosol extinguishing equipment can be divided into systems with and without thermal decomposition. In the first case there are some systems which are based on the formation of a fire aerosol directly at the site of fires. Conversely the aerosol without thermal decomposition is suitable for use in flood systems which is determined by application suitability itself, where the aerosol is transported to the fire by piping, dispersion or even natural flow. Aerosol generators are divided into so called cold and hot. Hot have more consistent extinguishing ability but their application is not always applicable due to the environment, the likelihood of a fire initiation. Therefore, the mixtures contain hydrate compounds in which water molecules are bound and the extinguishing agent outlet cools itself [3]. However, the given relative novelty of this fire-fighting substance it is necessary to examine in the long term alternative negative properties of the extinguishing object and in particular also flora, fauna and human health, whether in the intervening units or those occurring at the point fire. Some negative properties are already widely known, others need to be determined, documented and suggested by what steps the negative manifestations of aerosol substances used in the fire intervention can be significantly suppressed. Preferably an aerosol extinguishing agent can be used to extinguished the technical infrastructure in various types of energy collectors or technical corridors in premises of industrial constructions of individual enterprises or industrial zones.

2.2. Effects and consequences of aerosol extinguishing usage on humans

The historically first generation aerosol plant under the marked G1 was apparently invented in Tinjan in the Republic of China in 60’s last century [4]. Another big milestone from which the formation of aerosol extinguishing method is based are 70’s last century when this type was developed by the Russian agency for the cosmos research called “SOJUZ” [2]. Since then its expansion in the world has been steadily increasing and it is clear that this trend, given the emerging automated technologies, will at least not reduce.

In the case of the mixture itself and its composition, generator design, application methods and quality control, these devices are supervised by a standard based on regional requirements and legal restrictions with the differences, for example in USA, Australia, Russia, China, etc. The document setting out requirements and describing methods for the design, installation, testing, maintenance and safety of aerosol extinguishing agents in the Czech Republic is the document CSN P CEN/TR 15276 [5].

The ODP (Ozone depletion potential) and GWP (Global warming potential) values of aerosol extinguishing compared to halons are almost zero [6]. The risk to humans in general due to the size of generated aerosol particles, the size of which has been demonstrated by its own experimental measurement, the aerodynamic diameter of which is less 2.5 μm can accumulate on the walls of bronchi and lead to a chronic disease [7]. The respiratory tract and also the cause can be the case of acute respiratory disease [8]. In addition, the aerosol or burning of the mixture is accompanied by the most
time production of CO, NOx and other hydrocarbons which reduce the ability of O₂ transport in the human body and may be a transverse of cardiovascular disease [9]. In the mixture composition some types of equipment include, for example, trace amounts of hydrogen cyanide. The trace amounts of hydrogen cyanide are then released. The accompanying compounds are almost always water vapour, CO₂ and N₂ [10].

For these reasons strict regulations have been set in USA, Russian, China and Australia and precisely given volumes of maximum concessions which cannot be exceeded in a generation to minimise the impact on the disabled people health. Another essential factor resulting from the restriction of aerosol extinguishing agents for spaces normally inhabited by persons is the form forming fact a dense white “fog” which leads to a loss of orientation of the person in the space. It should be noted that aerosol extinguishing agents from the point of view in long-term exposure do not endanger person on life, prolonged stay in areas with its appearance can cause irritation of the airways, mucous membranes and eyes.

3. Modification method of aerosol mixture increasing extinguishing efficiency

The aim of experiments was to enrich the pyrotechnic composition for aerosol formation, thereby demonstrating its increased extinguishing efficiency, namely graphene-oxide products (GO) with Fullerene C60. Several contributions were devoted to the use of GO as flame retardant. Zhang and his collaborators observed in a conical calorimeter in a copolymer of styrene-butyl acrylate with a 1% weight-representation of GO, a decrease in the rate of heat release by 45%. GO oxide was used as an effective flame retardant for polystyrene and other thermoplastics.

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3.1. Carbon nanocomposites

Carbon is the essential element of organic compounds known for two allotropic modifications, diamond and graphite. Fullerene, the third modification, was discovered by Harold Krot in 1985 for which he was awarded the Nobel Prize in Chemistry. Graphene was first attached in 2003 by A. Geima’s group and K. Novoselov at the University of Manchester. It is a mono layer of graphite also known as a 2D crystal in which the carbon is arranged in regular hexagons and as such is considered as a basic carbon nanomaterial [15].

The detailed and actually carried out measurements showed a significant increase in extinguishing efficiency. The speed of the end-of-fire termination process itself in order up to 3% by enrichment weight of extinguishing agent basic mixture and as seen from the chemical compound composition these cannot increase the ecological burden.

4. Consequent impact examination of used extinguishing agents on building and buildings functional elements

The corrosive effect of the sediment from generated aerosol was tested on metallic specimens that were present on the floor in the experimental room, both in the first experiment (without fire) and second experiment (wood fire).

The metal plates had dimension 52x52x2 and had following composition: 1. zinc plating, 2. titanium-zinc, 3. aluminium, 4. brass, 5. stainless steel, 6. iron, 7. copper, 8. aluminium and copper anodized. After the end of the first experiment the metal samples were left in the place for 24 hours. Then the individual plates were washed with distilled water and dried. In the second experiment two sets of identical samples were laid on the floor in the experimental room. For the first set the follow-up process
was the same as for the samples in experiment 1. The plates for experiment 2 were transported to the laboratory and left with the contaminated surface for another 24 hours. Afterwards they were washed and dried. In this case we can speak about 48 hours contact with sediment.

Based on the visual comparison of platelet surface states it is noted that traces of corrosion, surface damage were not evident in sample 5 (stainless steel) and sample 8 (aluminium and copper). The difference between the samples of experiment 1 and 2 (with and without fire) it is also evident that the samples of which the corrosion has been damaged. In experiment 2 the surface damage was intensified. Time effect of contamination on the surface damage degree of this sample was confirmed, when comparing first and second sample sets. Samples 4 and 7 were the most affected by the action of sediments. The entire surface of the samples has been affected and violated for all these samples, see Table 1.

**Table 1.** Damage degree to metal surface after aerosol exposure.

| Metal type               | Exp 1 (24 hours) b/ | Exp 2 (24 hours) b/ | Exp 2 (48 hours) b/ |
|--------------------------|---------------------|---------------------|---------------------|
| 1. zinc plating          | X                   | XX                  | XXX                 |
| 2. titanium-zinc         | 0                   | X                   | XX                  |
| 3. aluminium (Al)        | 0                   | 0                   | XX                  |
| 4. brass                 | XX                  | XXX                 | XXX                 |
| 5. stainless steel       | 0                   | 0                   | 0                   |
| 6. iron                  | X                   | XX                  | XXX                 |
| 7. copper                | XXX                 | XXX                 | XXX                 |
| 8. Al,copper(anodized)   | 0                   | 0                   | 0                   |

Agenda of damage degree

0 – no damage
x – traces of corrosion
xx – partly corroded
xxx – corrosion affected by the entire surface
b) samples contact time with the sediments formed

**Figure 1.** Analysed conductor 1-CHKH-V fire retardant (red before experiment, blue after).

As in the previous case the effects of the generated aerosol were also subjected to a 30 cm length sample for 24 hours, selected commonly used nine electric conductors as well as part of the experiment. All of
them were subsequently analysed by IR spectroscopy method. As shown in the Figure 1, none of the samples were damaged after a prolonged exposure to the sediment.

5. Conclusion
As suggested in the experiments and examination results of the secondary effects of this commonly taking materials in connected place of possible fires, they also exhibit a certain corrosive effect on certain types of metallic materials. However certain types of metals, alloys, are not subject to corrosion at all or only partially. The same applies to commonly used plastic materials. Obviously this is a highly prospective substance, effectiveness which can continue to be modified and has a very limited impact on the design and lifetime of infrastructure itself. Also from the ecological point of view for the surroundings environment does not entail an increased burden on the environment which is conditioned by the composition mixture, its majority consist of oxygen acid salts such as KNO₃, KClO₄. Both authors of this paper have been working with the issue of aerosol extinguishing agents for a very long time. Their aim is to make a significant contribution to the research and development, critically analyse the secondary and negative properties to create a comprehensively ambivalent view of this technology and the substance itself.

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