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# CAUSES OF ACOUSTIC TRAUMA AMONG POLISH STATE FIRE SERVICE OFFICERS: A REVIEW OF INCIDENTS IN 2015–2022

Łukasz Dudziński<sup>1</sup>[A,B,D] , Łukasz Czyżewski<sup>2</sup>[C,D] ,  
 Tomasz Kubiak<sup>3</sup>[D] , Tomasz Milczarczyk<sup>4</sup>[B] 

<sup>1</sup> John Paul II Academy of Applied Sciences in Białą Podlaską, Poland

<sup>2</sup> Warsaw Medical University, Poland

<sup>3</sup> Academy of Applied Sciences Mieszka I in Poznań, Poland

<sup>4</sup> State Fire Service, Warsaw, Poland

## Background

A rare type of risk associated with firefighting activities and affecting the central nervous system (CNS) is acoustic trauma. The main causes of acoustic trauma in professional firefighters include long-term exposure to noise from fire engine sirens, emergency call alarms in the fire stations (fire halls), and the operation of equipment used during rescue and firefighting operations.

## Material/ Methods:

The study was based on an analysis of data obtained from the HR Department of the National Headquarters of the State Fire Service (NHSFS). The analysis included cases of acoustic trauma suffered by firefighters while on duty, which were reported to the control room of their firefighting units as rescuer accidents, and followed up with medical interventions.

## Results:

The average number of accidents among SFS firefighters per year during the study period was  $n=1.617$ . During the study period (2015-2022), there were seven incidents in which a total of 11 firefighters suffered acoustic trauma affecting the CNS and the organ of hearing.

## Conclusions:

To prevent on-duty accidents, both practical and theoretical training sessions are provided, covering measures aimed at reducing accident rates to minimum levels. Other important activities include hearing prophylaxis; medical examinations; breaks during work, appropriate organisation of work and the working environment; compliance with the applicable regulations, internal procedures and safety instructions; the use of personal protective equipment, and the good technical condition of vehicles and equipment.

**Keywords:** State Fire Service, firefighters, occupational health, acoustic, trauma

## SUMMARY

## INTRODUCTION

Firefighters serving in the Polish State Fire Service (SFS) are exposed to a variety of risk factors during their service. A rare type of risk associated with firefighting activities and affecting the central nervous system (CNS) is acoustic trauma. Trauma of this type may cause hearing loss, damage to the auditory nerve, and labyrinthine disorders. The main causes of acoustic trauma in professional firefighters include long-term exposure to noise from fire engine sirens, emergency call alarms in the fire stations (fire halls), and operation of equipment used during rescue and firefighting operations, e.g. winches, power generators, saws, cutters, etc. While on duty, firefighters may be exposed to a range of factors potentially inducing damage to the auditory system. The main factors listed in the firefighters' occupational risk sheet<sup>1,2</sup> include:

- explosions and detonations,
- operation of internal combustion engines in saws and other hand tools generating high levels of noise,
- vibrations generated by heavy equipment affecting the CNS including the organ of hearing,
- daily exposure to factors causing gradual hearing impairment (activities of a constant and repetitive nature), continuous noise from radios, computers, printers, photocopiers [see also: Antoniak 2019, Andruszkiewicz et al. 2011].

Other factors with a proven harmful effect on the CNS and the auditory system in firefighters include high levels of noise and sound pressure during rescue and firefighting operations, exceeding the intensity acceptable in other professions, and the fact that during most operations firefighters do not use safety ear muffs to minimise noise exposure. The lack of this type of hearing protection is due to the need to maintain constant communication in the course of rescue operations and analyse accompanying sounds on an ongoing basis in order to improve the safety of firefighting crews (enabling rapid evacuation, should it become necessary) and increase the effectiveness of operations<sup>3, 4, 5</sup>.

The most common sources of noise during firefighting operations, characterised by similar levels of generated noise, are listed in Table 1.

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<sup>1</sup> Ustawa z dnia 29 listopada 2002r. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy (Dz. U. z 2002r. Nr 217 poz. 1833).

<sup>2</sup> Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 16 września 2008 r. w sprawie szczegółowych warunków bezpieczeństwa i higieny służby strażaków Państwowej Straży Pożarnej (Dz. U. Nr 180, poz. 1115).

<sup>3</sup> Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 6 czerwca 2014 roku w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy. Dz.U nr 217, poz. 817

<sup>4</sup> Rozporządzenie Ministra Zdrowia z dnia 22 kwietnia 2005 r. w sprawie szkodliwych czynników biologicznych dla zdrowia w środowisku pracy oraz ochrony zdrowia pracowników zawodowo narażonych na te czynniki (Dz.U. z 2005 r. nr 81, poz. 716)

<sup>5</sup> Ustawa z 24 sierpnia 1991r o Państwowej Straży Pożarnej (Dz.U. z 2017r. poz. 1204 z późn.zm.)

Table 1. Factors adversely affecting the CNS and contributing to deterioration of hearing in the firefighters' working environment.

<b>Risk factor</b>	<b>Practical example</b>	<b>Noise level in dB</b>
Explosion	Explosion of gas cylinder	160
Operation of internal combustion engines	Trucks, power generators	125
Operation of fans	Smoke extraction fans	125
Operation of aircraft engines	Take-off and landing of HEMS	120
Road traffic	City centre traffic	90
Operation of equipment in confined spaces	Indoor machinery, demolition tools	85

## **MATERIAL AND METHODS**

### **Study design**

The study was based on an analysis of data obtained from the HR Department of the National Headquarters of the State Fire Service (NHSFS). The Department gathers data from all over Poland in the form of annual reports on accident rates which are compiled for each province separately. In December 2021, approval was obtained from the Head of the HR Department NHSFS to access and use the data pool. On-duty accident reports contained detailed data including the number of accidents and number of injured firefighters, age and length of service of the injured, and causes and circumstances of accidents (injuries). In addition, the data were broken down into individual and collective accidents, and duration and type of medical treatment. The available databases were searched to identify incidents involving acoustic trauma sustained by firefighters. The review was conducted for the whole of Poland, spanning the years 2015-2022.

### **Ethical considerations**

Since all personal data of the firefighters described in the paper are confidential, neither the consent of the ethics committee nor the consent of the injured officers needed to be obtained for the H&S data analysis. The cases described are fully anonymised, and the review was conducted in line with the principles of the Declaration of Helsinki.

### **Data collection**

The analysis included cases of acoustic trauma suffered by firefighters while on duty, which were reported to the control room of their firefighting units as rescuer accidents, and followed by medical interventions. All cases where acoustic trauma resulting in a firefighter's temporary incapacity for service was sustained off-duty were excluded from the analysis.

The authors compiled a set of data that met the inclusion criteria based on a review of official documents which were named differently over the years:

- analysis of accident rates in the SFS,
- analysis of the state of health and safety at work/in service in the organisational units of the SFS

### **Study limitations**

The review spanned a total of seven years, but the number of cases identified in this period was fairly limited. The analysis included incidents that caused sudden-onset disorders affecting the organ of hearing and the central nervous system, preventing firefighters from continuing their tasks and requiring medical intervention:

- subjective complaints – headache, dizziness, balance disorders, tinnitus;
- pathologies – hearing impairment.

The reported incidents were formally recorded in the documentation as SFS rescuer accident reports. All factors that had an adverse effect on the organ of hearing but were of a permanent (chronic) nature in the service of firefighters and could not be attributed to any specific event, i.e. a rescue and firefighting operation or other official duties, were excluded from the review. Importantly, the authors had no access to the clinical records of hospital treatment (if any).

## **CASE REPORTS**

During the study period (2015-2022), there were seven incidents in which a total of 11 firefighters suffered acoustic trauma affecting the CNS and the organ of hearing. The incidents are described in detail below in chronological order.

**Incident 1.** Year: 2017. Location: Łódzkie Province. Number of injured: 1.

An explosion occurred during firefighting operations carried out at the request of the police, resulting in acoustic trauma to one firefighter. The symptoms that occurred after the incident included mixed hearing loss and tinnitus involving both ears.

**Incident 2.** Year: 2017. Location: Lubuskie Province. Number of injured: 1.

A firefighter sustained acoustic trauma in the right ear, while participating in chemical training. The cause of the injury was an explosion of a pyrotechnic material used during simulation exercises in an enclosed space (a bunker simulating a utility room). The symptoms associated with the incident included tinnitus, sensation of ringing in the ears, and hearing impairment, deteriorating over time.

**Incident 3.** Year: 2017. Location: Podkarpackie Province. Number of injured: 1.

During a firefighting exercise to extinguish an internal building fire, a firefighter using the required PPE suffered an acoustic trauma due to a powerful explosion of a pyrotechnic material used for simulations. The victim fell to his knees and was evacuated with the help of another firefighter from the same firefighting crew. As a result of the incident, the firefighter was stunned and disoriented, with effects of the incident including pain felt in the head and left ear, and damage to the left auditory nerve.

**Incident 4.** Year: 2018. Location: Łódzkie Province. Number of injured: 4.

Four firefighters who were in a garage located in a SFS fire station yard were exposed to acoustic trauma following a rapid rise in sound pressure in one of the batteries supplying the starter of a fire engine. The increase in sound pressure level was caused by the vehicle's faulty battery. Two firefighters sought medical attention on the day of the incident because of a feeling of discomfort in the head. Another two firefighters consulted a medical practitioner on the following day because of persistent discomfort in the ear.

**Incident 5.** Year: 2018. Location: Warmińsko-Mazurskie Province. Number of injured: 1.

While on duty, a firefighter was repairing a snow clearing machine. As he was adjusting the ignition, a loud shot-like sound occurred, as a result of which the firefighter suffered acoustic trauma to his right ear. The symptoms included tinnitus and sensation of hearing impairment.

**Incident 6.** Year: 2018. Location: Mazowieckie Province. Number of injured: 1.

During a gazebo fire in the overnight hours, a SFS firefighter sustained a hearing injury due to an explosion of a camping gas cylinder. In addition, the firefighter experienced a range of CNS symptoms including dizziness, vertigo and ringing in the ears, which persisted for a few hours.

**Incident 7.** Year: 2018. Location: Wielkopolskie Province. Number of injured: 3.

Three firefighters were injured because of exposure to high noise levels during the repair of a failure in a medium pressure gas pipeline. Immediately after the incident, the firefighters reported no complaints. However, after a few hours, they experienced an array of symptoms including bilateral tinnitus and discomfort in the head.

## RESULTS

The average number of accidents among SFS firefighters per year during the study period was  $n=1,617$ . The accident rates presented in Fig. 1 show a downward trend both in terms of the total number of accidents involving individual firefighters and collective accidents. While the proportion of acoustic trauma cases in the total number of incidents is small, the proportion of two acoustic trauma-related collective accidents in the total number of collective injuries is noticeable in two years (2017 and 2018) during the study period: 23% in 2017 and 40% in 2018.

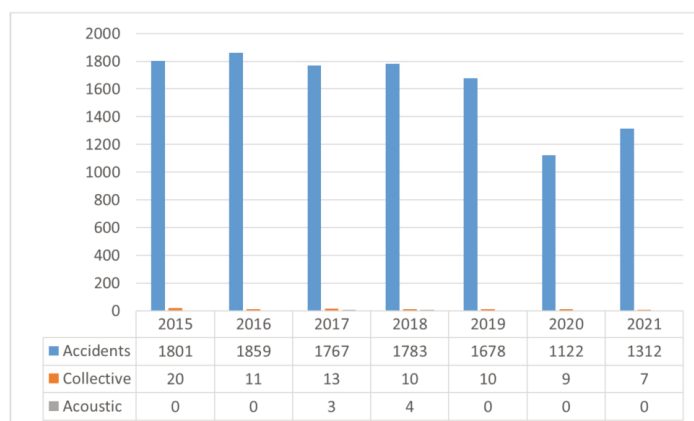


Figure 1. Number of injured firefighters in 2015-2021

Source: H&S report on accident rates among firefighters in 2015-2021. NHSFS <sup>6</sup>

<sup>6</sup> Komenda Główna Państwowej Straży Pożarnej, Biuro Kadr- raport o stanie wypadkowości wśród funkcjonariuszy PSP.

## DISCUSSION

Hearing impairment in professional firefighters can be permanent and result in serious communication problems as well as interfering with the ability to carry out daily activities. Firefighters should use appropriate hearing protection and be aware of the dangers, risk factors, and basic concepts and differences associated with the physical nature of sound and physiology of the auditory system. Of note, the subjective perception of loudness is not directly proportional to sound pressure, so a double sound pressure is not linked to a perceived doubling of loudness <sup>7</sup>.

In addition to the intensity (level) of sound expressed in decibels (dB), other factors requiring attention include the frequency and audio frequency range audible to humans (in the range of 20 Hz – 20 kHz). Of note, sound pressure is also generated beyond the audible frequency range, which is potentially dangerous to firefighters (acoustic trauma without identifiable sound effects) [see also: Pleban et al. 2000, Szymańczyk et al. 2017].

The tasks carried out by firefighters encompass mainly fires, building collapses, traffic accidents as well as other incidents endangering the life and health of citizens and the safety of property, and the elimination of local hazards. During these activities, firefighters are at risk of various types of injuries due to exposure to factors affecting the respiratory system and the skin, but also the CNS. Firefighters carry out operations in diverse weather conditions and at extreme temperatures. In addition, they are exposed to moisture and a range of chemical and physical factors (e.g. pressure, noise, etc.). The topic of excessive noise in the workplace has been extensively covered in the literature. Aside from their harmful impact on hearing, high noise levels also produce other adverse health effects within the cranial nerves such as reduced mental performance, decreased precision of movement, and impaired vision. In one study, the authors analysed noise exposure levels in selected areas of a mechanical biological treatment plant to determine the maximum and average exposure of workers to this factor [see also: Gronba-Chyła 2022].

A study by Guthrie focused on investigating psychophysiological responses to post-traumatic stress by prospectively evaluating auditory startle responses in a group of 84 firefighters before and after exposure to trauma using 100 dB acoustic startle stimuli generated at 30-55 second intervals [see also: Guthrie et al 2005].

Bohl determined whether firefighters suffered hearing loss due to occupational noise based on the results of periodic audiometric testing in the population of two large cities. The author showed that firefighters did not experience excessive hearing loss because of exposure to harmful conditions while in service. The impairment of hearing in the firefighters under study was attributed primarily to age [see also: Bohl et al. 2005]. Based on own observations, out of 12 firefighters who sustained acoustic trauma in five cases the injury occurred during rescue

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<sup>7</sup> [www.audio.com.pl/vademecum/faq/akustyka/22148-czym-rozni-sie-cisnienie-akustyczne-od-glosnosci](http://www.audio.com.pl/vademecum/faq/akustyka/22148-czym-rozni-sie-cisnienie-akustyczne-od-glosnosci)

operations, in another five cases – during equipment maintenance, and in two cases – during exercises.

Ide concluded that sensory deprivation might increase the level of hazard, while good hearing was essential for firefighters in most tasks at the scene of operations. Furthermore, hearing loss was found to be a normal part of the ageing process, and its progression rates varied between individuals and risk factors. The author also pointed out other rare causes of damage to cranial nerve function in firefighters, including acoustic neuromas (a rare type of neoplasm) [see also: Ide 2007].

Snapp notes that the hearing loss in firefighters occurs through chronic (regular) exposure to hazardous noise levels. Own observations identified the causes of the disorders as sudden-onset, violent events (one-off exposures) [see also: Snapp et al. 2022]. Similar conclusions were reached by Broeys and Kang [see also: Broyles et al 2019, Kang et al. 2019] who studied aggregated 24-hour (i.e. equal to a typical firefighter shift) noise samples. Polish firefighters undergo induction, periodic, and on-the-job training, and receive appropriate protective equipment dedicated to rescue and firefighting operations, which significantly reduces the incidence of injuries, including acoustic trauma. Of note, noise is listed as a physical risk factor on referrals for annual periodic examinations. In addition, Polish professional firefighters, regardless of their rank, undergo periodic laryngological consultations and audiogram examinations<sup>8</sup> [see also: Kurek et al. 2019, Ankowski et al. 2019].

## CONCLUSIONS

High frequency of mandatory occupational health and safety training – including induction, periodic and refresher training types (operation of equipment, engines) – contributes to reducing the number of acoustic trauma cases. To prevent on-duty accidents, both practical and theoretical training sessions are provided, covering measures aimed at reducing accident rates to minimum levels. Other important activities include hearing prophylaxis; medical examinations; breaks during work, appropriate organisation of work and the working environment; compliance with applicable regulations, internal procedures and safety instructions; use of personal protective equipment, good technical condition of vehicles and equipment. Firefighters are exposed to the risk of hearing loss predominantly through sudden unforeseen acoustic events, and less commonly through exposure to workplace noise and excessive noise levels.

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### **Corresponding author**

Łukasz Dudziński

John Paul II Academy of Applied Sciences in Biała Podlaska

Sidorska 95/97, 21-500 Biała Podlaska, Poland

e-mail: lukasz\_dudzinski@o2.pl