

Exposure to firework noise in festivals

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Summary

Exposure to impulsive noise produced by fireworks has a higher level of risk to human health than exposure to continuous noise. Aware of the problems related to this type of exposure, the European Union (EU) published the Directive 2013/29/EU that establishes a maximum sound level of 120 dB(A, imp) at several distances of launching point depending on the type of artefact. The present work aims to investigate the levels of exposure to which the population and workers are exposed when participating in festivals or pilgrimages. This research was done in northern Portugal during summer. Five events were evaluated and parameters such as LAeq, LA10, LA50, LA90 were recorded. In the measurements, the sound level meter was on during the time the explosions occurred, and in one case that was about 30 minutes. During the measurements people of all ages, from babies to seniors, as well as professionals such as musicians, police officers, fire-fighters, merchants and others, were seen without adequate protection, exposed to values that exceed the maximum level stated by the EU and in some cases reaching the peak of 137 dB(C), which is a high risk to those exposed. This paper presents the measurements done and the main results found. For example, LAeq values ranged from 87 to 100 dB and the maximum statistical sound levels were 104 dB for LA10, 88 dB for LA50 and 79 dB for LA90. The LEX,8h was evaluated for the firework technicians, for the sound and light operators and for the police officers in the events. The limits proposed by the EU Directive 2003/10/EC were exceeded in the case of the police officers and sound and lights operators, and for those responsible for the detonation of fireworks (blasters).

PACS: 43.50.Qp, 43.50.Rq, 43.28.Hr

1. Introduction

Fireworks are commonly used during festivities and popular celebrations because of their sound, brightness and sudden burst of colours, expressing the festive mood. Since the early 1990s, epidemiological studies have indicated that leisure noise posed a substantial danger, especially for children, adolescents and young adults that may produce irreversible hearing loss [1]. This is basically due to the large exposure in the propagation of very noisy attractions, fireworks and exposure to electronically amplified music vendors or concerts [1,2].

1.1. Impulsive noise in leisure activities

While the noise exposure to continuous music is characterized mainly with a lower degree of impulsive sounds, in leisure activities, impulsive noise can be observed like in practice target shooting, toy guns and fireworks. This type of leisure noise can cause damage to the ear due to the following reasons [1]:

- Exposure to impulsive noise has a higher level of risk to human health than continuous noise;

- The subjective intensity of impulsive noise, due to its short duration, does not match the peak level;
- In leisure activities almost no attention is paid to the possible harmful effects produced by the exposure, as these noises are subjectively associated with a positive experience such as the joy and beauty produced by the explosion of fireworks.

1.2. Exposure limits for noise fireworks

Exposure limits have been required for the use of fireworks for instance in the UK and since 2004 a regulation was adopted for controlling its noise during use [3]. It states that fireworks can not be used between 11pm and 07am (but with exceptions). However, for all kinds of festivities, it is not allowed to use fireworks that produce a sound level of more than 120 dB(A) at 15 meters from the source [3].

Studies in India have sought to reduce the noise produced by fireworks to the sound level of legal standards established since 2005, which is 125 dB(A) at 4 meters [4,5]. Aware to problems in the use of fireworks the European Union published the Directive 2013/29/EU that establishes ratings for fireworks (*F1*, *F2* and *F3* types), a safety distance of 1, 8 or 15 m for their use and a maximum sound level of 120 dB(A, imp) not to be exceeded or an equivalent noise level as measured by another appropriate method, at the safety distance [6].

2. Methodology

The goal of this study was to investigate the noise produced by the use of fireworks in popular festivals and pilgrimages. This study was conducted in the Portuguese cities of Vila Nova de Gaia (VNG), Porto (P) and Matosinhos (M). Table 1 shows the number of events evaluated for each municipality. These cities were chosen because they have a great amount of people exposed to noise of fireworks in the events of interest. In some cases, such as in the feast of São Pedro de Afurada (VNG), about 15.000 people can be exposed to noise during the fireworks show. The measurements were done using a class 1 Brüel & Kjær, model 2236 sound level meter, with a type 4188 microphone. The evaluations were performed in the presence of the local people and as close as possible

from the sources of noise. This distance was not smaller than 15 meters depending on the restricted areas around the fireworks launching area. The duration of the measurements varied according to each event and Table 2 displays the measurement duration (T) and the distances (D) between the measuring position and the exposure source. The parameters evaluated were: LAeq, LA10, LA50, LA90, LAminimum, LAmaximum and Lpeak.

Table 1 Municipalities and total assessed events.

Town	Population (approx.)	Number of events evaluated
V. N. Gaia (VNG)	302.100	3
Porto (P)	237.600	1
Matosinhos (M)	175.500	1

Table 2 - Time (T) and distance (D) evaluation of the fireworks.

EVENT (dates)	T (min.)	D (m)
Vila Nova de Gaia (VNG)		
São Pedro de Afurada (SPA) (June, 29, 2014)	16	100
São Cristóvão (SC) (Mafamude) (July 27, 2014)	10	150
Bom Jesus do Monte (BJM) (V. Paraíso) (August 4, 2014)	12	20
Porto (P)		
N ^a .S ^a da Saúde (NSS) (Paranhos) (August 14, 2014)	13	25
Matosinhos (M)		
Senhor de Matosinhos (SM) (June 10, 2014)	31	20

The Figure 2 shows an example of a time evaluation of a fixed type firework and fireworks installed on boats. The fixed fire is made primarily of various types of dolls set in trunnions that are started by pressing a fuze that makes them rotate around an axis, producing a beautiful fireworks' show, which attracts the public, particularly

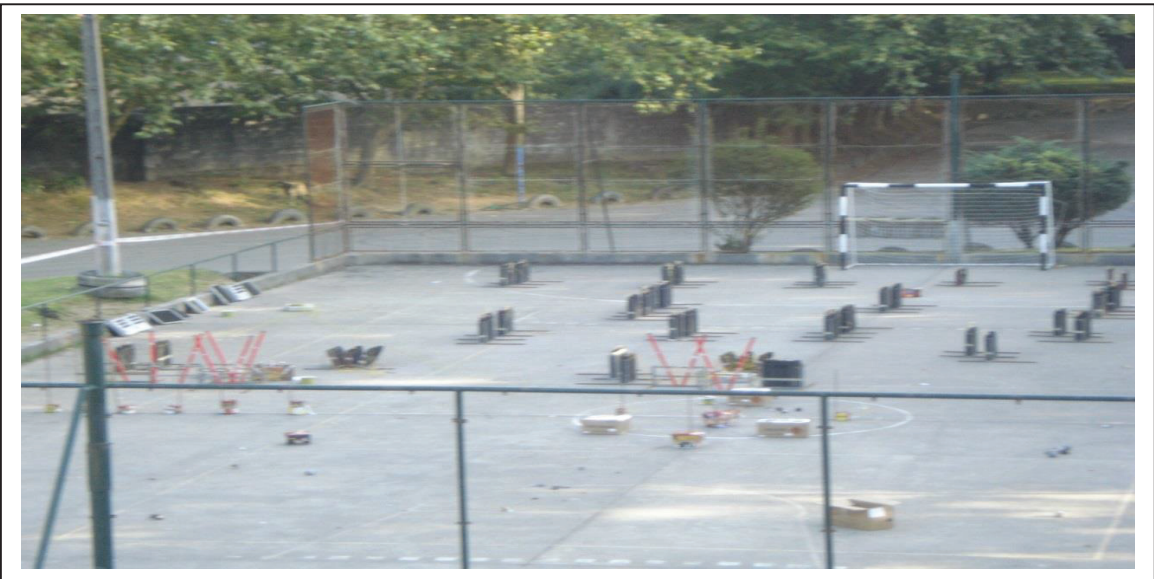
children. The presence of numerous people of various ages can be seen exposed to impulse noise produced by the explosion of fireworks.

Figures 1 and 2 – (Left) Fixed type fireworks noise assessment and exposed population, Festivity of Senhor de Matosinhos (SM) and (Right) firework noise evaluation installed on boats in Rio Douro- Festivity of São Pedro da Afurada (SPA) (Vila Nova de Gaia).



Figure 3 shows the load of fireworks used in the feast of Bom Jesus do Monte (BJM - VNG) where roman candles type fireworks (orange and elongated), batteries (boxes) and rocket launchers, can be seen. The explosions of the firework occur by driving an electronic system operated by a professional who is exposed to noise throughout the period. In all cases this professional is supported by other workers who also are exposed to the noise produced.

Figure 3 – Load fireworks, Festivity of Bom Jesus do Monte.



To obtain the events' LEX,8h three categories of workers were assessed which seemed to be the most exposed to high levels

of noise: Those responsible for the detonation of fireworks, the sound and light operators and the police officers. To determine the LEX,8h of the workers responsible for the fireworks, the LAeq on site was initially determined and then simulated for the LAeq value at the distance of the actual exposure, as shown in Table 3. From this new value of LAeq, the value of the LEX was calculated. For the calculation of the LEX,8h the mathematical model used is shown in Equation 1 and considered the exposed times (Te) obtained during the evaluations and inserted in Table 2 and T₀ assumes the value of 480 minutes.

$$LEX,8h = LAeq_{Te} + 10 \log (T_e/T_0) \quad (1)$$

Table 3 - Distance for the LEX,8h calculation for the fireworks technicians.

EVENT	D LEX,8h (m)
São Pedro de Afurada (SPA)	20
São Cristóvão (SC)	10
Bom Jesus do Monte (BJM)	10
N ^a .S ^a da Saúde (NSS)	10
Senhor de Matosinhos (SM)	10

3. Results and discussion

The results of the LAeq, LAm_{ax}, LA_{min} and LC_{peak} measurements are shown in Figure 4. Considering the parameter that represents the level of the weighted continuous equivalent sound level (LAeq), the highest value was in the Festivity of São Caetano (SC, Vila Nova de Gaia), although with less exposure time for the event participants. In all events, if we consider the parameter adopted as ideal limit by Directive 2013/29 /EU, *i.e.* the maximum value of the sound level, weighted in time and frequency, for a given time interval (L_{max}), we find that none of them exceeds 125 dB(A). However, when looking at the parameter corresponding to the instantaneous value of the maximum sound level in a given time interval (LC_{peak}), except for the Festivity of São Pedro da

Regarding the sound and light operators, the apparatus was placed near the ears of these, and in this case, considered an exposure time (Te) 120 minutes obtaining the LAeq. Based on the same mathematical model the value of LEX,8h was determined.

For the calculation of LEX,8h of the police officers, were considered the noise produced by fireworks, by the musical shows and by the amusement park attractions. After determining LAeq in various points the LEX,8h was found for each event, depending on the mathematical model (Equation 2), and the exposure time was normalized to 10 minutes for fireworks, 90 minutes for musical concerts and 60 minutes for the noise exposure of amusement park attractions.

After obtaining the LEX,8h, they were compared with the exposure values set by Directive 2003/10/EC.

$$LEX,8h = 10 \log \left[\frac{1}{8} \left(\sum_{k=1}^3 T_k 10^{(LAeq,Tk/10)} \right) \right] \quad (2)$$

Afurada (SPA), all other present values that may pose a risk to the public, especially for babies and children.

The party SM used a fixed type firework. In this event a survey type questionnaire was tested, in order to understand the participants' perception regarding the risk of exposure to noise. The population considers the level of noise produced as mostly "harmless". However, this kind of fireworks produced a peak of 137 dB(C) sufficient to produce hearing damage.

In none of the evaluated events, there was the use of hearing protection by any professional present.

Figure 5 shows the results related to the statistical parameters LA₁₀, LA₅₀, and LA₉₀. The evaluated statistical values serve as the basis for creating a criterion for acoustic rating the events using fireworks.

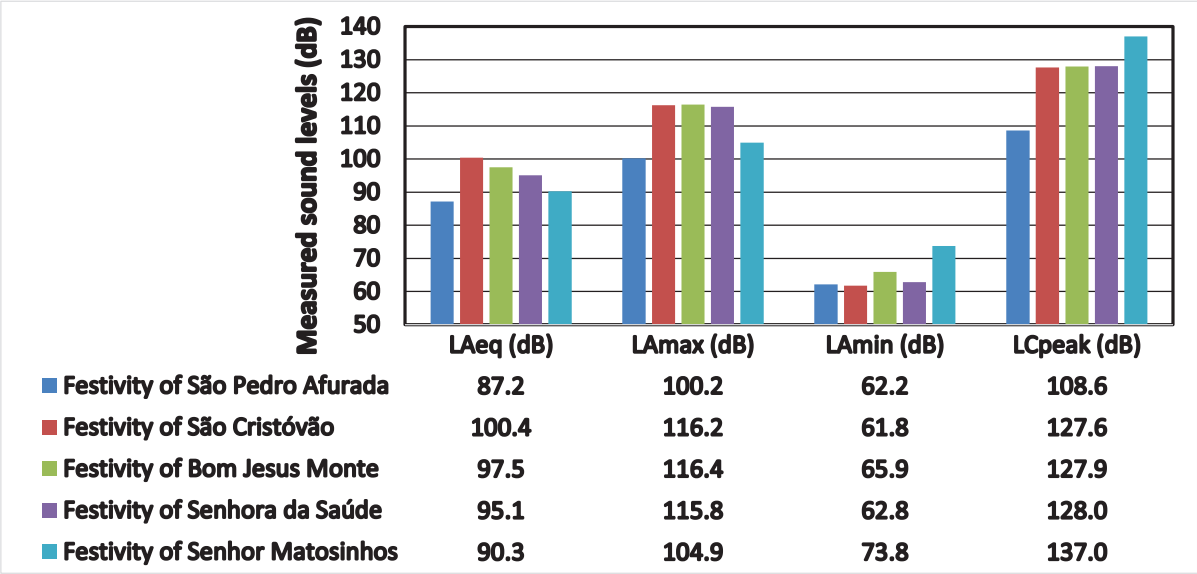


Figure 4- Results of LAeq, LAmx, LAmin, and LCpeak.

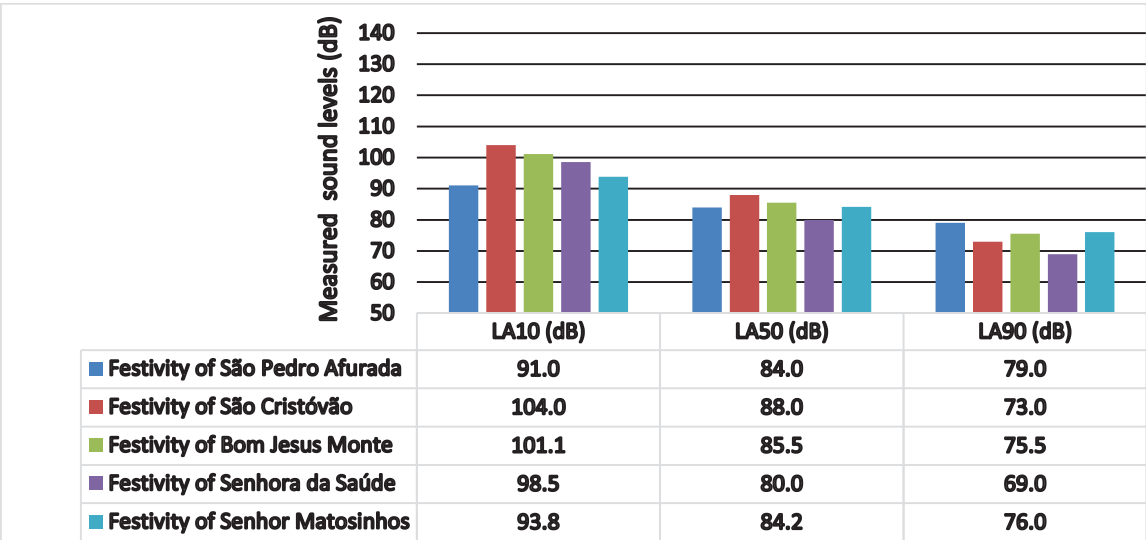


Figure 5 - Results of statistical parameters LA10, LA50, and LA90.

The results of the LEX,8h and LCpeak can be seen in Table 4 where it can be observed that for the sound and light operators, all the values recorded on the events are above the higher exposure level value that triggers the action (LEX,8h = 85 dB(A)) and above the exposure limit value of Directive 2003/10 EC, which is 87 dB(A). The situation is repeated for the exposure of police officers present in the evaluated events. Regarding the professionals responsible for the explosions of fireworks this value was exceeded only on the festivity of São

Cristóvão (SC). In the other cases, the values of LEX,8h are below the lower exposure level that triggers the action, which is 80 dB(A). However, the lower action value was exceeded for the case of firework technicians and police officers for the peak values.

In Table 4 the values in red relate to values above the exposure limit value of 87 dB(A) and 135 dB(C). It is noteworthy that none of the evaluated professionals used hearing protection.

Table 4 –Results for the LEX,8h and LCpeak measurements (the red values indicate a non compliance with the EU directive).

EVENT	Sound and light operators		Police officers		Firework technicians	
	LEX,8h (dBA)	LCpeak (dB)	LEX,8h (dBA)	LCpeak (dB)	LEX,8h (dBA)	LCpeak (dB)
S. Pedro da Afurada (SPA)	90.1	107.2	90.5	108.0	71.6	108.0
S. Cristóvão (SC)	90.2	126.9	96.9	128.2	105.4	127.9
Bom Jesus do Monte (BJM)	97.3	127.8	100.6	127.9	71.1	127.9
N ^a Senhora da Saúde (NSS)	88.5	104.9	100.7	128.0	71.7	128.0
Senhor de Matosinhos (SM)	94.7	126.4	94.2	137.0	72.4	137.0

4. Conclusions

Although the values found for the LA_{max} meet the latest directive adopted by the EU, the peak sound levels found can produce hearing damage in the population participating in these events, particularly in infants, children and youth. The risk of occupational hearing loss can be checked for all assessed professionals, with greater emphasis to the sound operators and police. It is important to continue the evaluations aiming to better assess the acoustic phenomenon found, making it possible to develop an acoustic rating for such events.

5. Acknowledgement

Acknowledgement is due to the organizers of the events that allowed this work to be developed, to the Laboratory of Acoustics of the Faculty of Engineering (University of Porto, Portugal) for their support in orientation and the study, and the Federal Institute of Pernambuco - Brazil, for allowing the participation in this research.

6. References

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