

Sound exposure and noise pollution at outdoor events

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A working group of the AES Technical Committee on Acoustics and Sound Reinforcement recently published their report, "Understanding and managing sound exposure and noise pollution at outdoor events." The report is intended to present the current state of affairs surrounding the issue of outdoor event-related sound and noise. The two principal areas of investigation are sound exposure on-site and noise pollution off-site.

INTRODUCTION

Sound exposure and noise pollution due to outdoor entertainment events carry implications spanning public and private life. This isn't a new issue. The AES library contains papers published over 50 years ago discussing these issues, although judging by the continued discussion and debate, it's clear that the industry has yet to produce a universally accepted solution (or even a robust understanding) of the relevant problems.

A working group of the AES Technical Committee on Acoustics and Sound Reinforcement recently published their report, "Understanding and managing sound exposure and noise pollution at outdoor events," which is available as AES Technical Document 1007.1.20-05 [1]. The report is intended to present the current state of affairs surrounding the issue of outdoor event-related sound and noise. The two principal areas of investigation are sound exposure on-site and noise pollution off-site. These issues are different in nature and require distinct approaches to mitigate the associated negative short-term and long-term effects.

A significantly condensed summary of the report's findings is presented here for the interested reader, although the full report

should be read to gain a complete view of the working group's findings.

SUMMARIZED FINDINGS

The report demonstrates that it is possible to deliver appropriate sound levels to audience members in a safe manner (limiting the risk of hearing damage) while also minimizing annoyance in local communities. The working group aims to cooperate with regulating bodies and live music associations to ensure the delivery of high-quality and enjoyable live entertainment while keeping audiences safe and minimizing annoyance in the local communities.

It is the view of the working group that solutions to the on-site and off-site problems should begin with a well-informed sound system design. Only with a properly designed sound system can sound/noise regulations be realistically applied.

Overall, the dual goal in sound system design is to minimize noise propagating to local residential areas while delivering consistently high-quality and appropriate listening experiences for all audience members. The following primary sound system design goals should be targeted: (1) provide a uniform audience coverage; (2) minimize noise pollu-

tion to surrounding noise-sensitive off-site areas; (3) minimize noise pollution to other stages and designated quiet areas on-site; (4) provide an appropriate sound level at the front-of-house mix position; (5) ensure all audience members are protected from over-exposure to sound.

The first step to achieve these goals is to optimize the system using an appropriate (often system-specific) direct sound simulation tool, considering both on-site and off-site issues. This will help to balance coverage, audience exposure, and, in the first approximation, off-site noise pollution. The second step is to use a suitable noise propagation model, ensuring local noise regulations are satisfied. If there are no sensible noise regulations or guidelines in place, it is helpful to use appropriate guidelines from another region to set up an example of responsible and sustainable noise management. Finally, a communication strategy with local residents should be implemented.

Uniform audience coverage allows engineers and acoustic consultants to precisely track audience sound levels without the need for many monitoring locations (ideally a single measurement location at the front-of-house mix position). This makes audience

sound exposure monitoring and management more practical and accurate, while simultaneously ensuring all audience members receive a high-quality listening experience.

The underlying principle for achieving uniform audience coverage is to optimize the distance between the loudspeakers and the nearest audience member—a focus that has carried over to the World Health Organization (WHO) Make Listening Safe Initiative [2], where a number of the report's authors are contributors. Ground-based subwoofers are typically the worst offender of this principle, where subwoofers are routinely placed within a few meters of audience members, which have been found to regularly deliver over 140 dBC peak.

While the effects of long term and/or high intensity sound exposure in the high frequency range (above approximately 200 Hz) is relatively well-known and covered in regulations pertaining to occupational noise exposure, there is significantly less knowledge (and consensus) on the effects of such exposure in the low-frequency band (especially in the infrasound region, below 20 Hz).

Infrasound is becoming increasingly common at live events and is a problem that must be better understood in the context of this industry to ensure risks to permanent hearing damage aren't being inflicted on both audiences and working personnel. It must be noted that considering the intensity and duration of low-frequency sound exposure to audience members at large events, standard ear protection is ineffective at low frequencies and is therefore an unacceptable solution.

Consequently, the use of ground-based (beam-forming) subwoofer arrays is controversial as they are very helpful, if not indispensable, to minimize off-site noise pollution at low frequencies, which causes the most annoyance, but have the potential to cause harm to nearby audience members and staff. Therefore, the use of ground-based subwoofer arrays should be carefully considered and simulated beforehand. Perceptually-transparent decorrelation can be applied to flown left/right subwoofer configurations to avoid any resulting inconsistent horizontal coverage [3], negating one of the justifications for using a ground-based subwoofer array. Care must be taken, however, to ensure off-site low-frequency noise pollution is still adequately controlled.

The report presents a broad and comprehensive overview of noise pollution regu-

lations to highlight areas of good and poor practice throughout the world. The collection of regulations presented are to be viewed as wide-reaching, but not entirely comprehensive as there are well over one thousand regulations across the globe on the international, national, regional, and local levels. Nonetheless, trends are clear (as illustrated in Fig. 1 and areas of good practice stand well apart from many of the other examples.

Of all the regions in the world, Europe is most forward-thinking in terms of noise regulation for entertainment events (and general consistency of environmental noise regulations). This is in large part thanks to the clear guidelines developed by the WHO over the past twenty years focused on community noise in Europe [4].

This is not saying that the noise regulations in Europe are perfect. There is room for improvement and expansion. The vast majority of regulations are based on LA_{eq} measurements, meaning that annoyance due to low-frequency musical content will be missed by such approaches and may not give a clear indication of the true situation regarding noise pollution from outdoor entertainment events. Similarly, a significant portion of sound energy rests outside the A-weighting curve on site at live events (in the subwoofer band), but all reviewed audience sound exposure regulations use LA_{eq} for their primary limits (some have secondary LC_{eq} limits). The use of A-weighting in all instances of sound/noise monitoring at live events is likely to cause issues, but further research is necessary to confirm this.

Environmental noise propagation models have existed for many years and are used extensively in atmospheric and underwater acoustics. In the context of the report, a special noise propagation model is required for use during the sound system design process. Unlike standard noise analysis where individual noises are incoherent, noise from outdoor entertainment events comes from multiple loudspeakers that output approximately coherent signals. Consequently, complex summation (as opposed to energy summation) is required to accurately predict noise levels at receiver positions. There are a

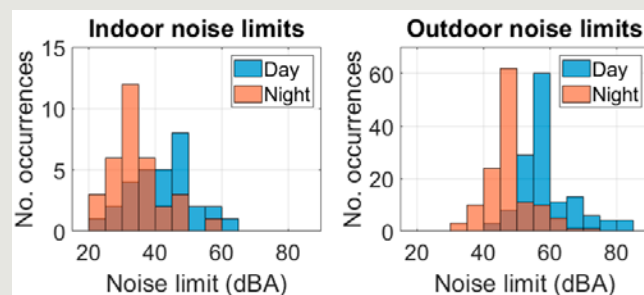


Fig. 1 Histograms of indoor and outdoor residential noise limits from countries across the world [1]

number of commercially-available software packages that address this need.

In more practical terms, it is clear that event-based noise pollution does not directly cause hearing damage. Instead, it results in annoyance and sleep disturbance. Both lead to increased stress and, in the long-term, can contribute to both mental and physical health damage.

There exists a wealth of evidence indicating that annoyance can be minimized through an effective communication campaign with the local residents in the run-up to and during an event (in addition to implementing technical means to decrease noise levels). The greater the transparency of information, the better. A well-thought out noise management plan will often be sufficient to mitigate the majority of noise complaints due to an event. Such practice is currently implemented at large events in the UK and Europe. However, the goal is to minimize the noise pollution and not just the number of complaints.

KEY QUESTIONS ARISING

The report concludes with a set of questions that must be addressed to gain a better understanding of sound exposure and noise pollution at outdoor events. These questions can be separated into three categories: (1) healthy ears; (2) limited annoyance; and (3) sound system design.

Healthy ears

What is the best approach to measuring and monitoring audience sound exposure? What is an appropriate sound exposure limit for the audience? Does Noise-Induced Hearing Loss correspond to Music-Induced Hearing Loss? Are audience members (and staff) situated near ground-based subwoofer systems receiving dangerous noise doses? What are the physiological and psychological effects of high-levels of infrasound? Considering the previous question, does standard hearing pro-

tection available at events do anything to protect from hearing damage at low frequencies? What should be done to best educate audiences of the risks of sound-exposure at large events?

Limited annoyance

What is best practice to achieve high-quality audience listening experiences while minimizing off-site noise? Is there an opportunity to standardize entertainment event noise regulations? When analyzing acoustic models for noise prediction, should it be standard practice to include the stage monitoring system? When planning noise control measures, is there any practical method to predict and correct for the effects of sound refraction or is this uncontrollable? What is the most accurate and practical method for predicting noise annoyance in the community? Is it possible to standardize noise monitoring practices at large-scale outdoor events? How problematic are room-modes in domestic environments that receive music-based low frequency noise pollution? How effective are in-room noise cancellation devices?

Sound system design

Do flown subwoofer systems generate greater noise pollution off-site? Can the same audience experience achieved with a ground-based subwoofer system be delivered with a flown subwoofer system? Do source-oriented systems result in lower audience sound exposure levels? Should greater use of virtual bass be recommended to mitigate noise issues? Is it possible to exchange sound level for system bandwidth? If a stage structure causes the degradation of a subwoofer system's cardioid pattern in the stage and audience area, is this effect seen in the extreme far-field (i.e., the community)? How effective are secondary sound systems? Is it worth exploring more widespread use of low-frequency absorbing tubes at live events? Is automatically mixing to the sound level limit practical? How can large-scale PA shoot-outs be conducted to guarantee reliable and unbiased data? Is it worth standardizing this?

While some of the above questions have already been (at least partially) answered, many are still open to debate. All are expanded upon within the full report [1].

HELA INITIATIVE

The report makes clear the complex international regulatory climate surrounding sound

exposure and noise pollution from outdoor events. This is in large part due to the lack of unbiased scientifically-based research needed to create unambiguous, practical and effective regulations in these areas. Much of this is identified in the WHO's 2018 community noise guidelines [4]. While some regulations appear to be sensible and practical, the confusion stemming from the contradictory data identified in the report has resulted in poor sound/noise control practices at many large-scale live events.

We propose that a live event sound/noise management initiative be created, focused on the dual nature of the problem: on-site sound exposure and off-site noise pollution. Such an initiative would detail current best practice in these areas and would allow venues, events, manufacturers, and even possibly performers to pledge voluntary compliance. In addition to the primary goal of standardizing practice at large outdoor live events, the initiative would also support and take the lead on key research required to answer the questions raised here. Such research would eventually inform work on new regulations and standards. Bringing together professionals committed to achieving these goals would gather the expertise and drive research to ensure on-site and off-site experiences of outdoor events are as safe and enjoyable as possible.

The working name for this initiative is The Healthy Ears, Limited Annoyance (HELA) Initiative. Healthy Ears indicates a commitment to preserving healthy hearing of all individuals on an event site (whether they are working, volunteering, or in attendance). Limited Annoyance focuses on the off-site community, striving to avoid excessive annoyance due to noise pollution from an event. The word *limited* is used as it is understood that it is impossible to avoid all annoyance. Limiting noise-based annoyance as much as reasonably practical must be the target. The acronym, HELA, is a play on a common slang term used in California, "hella" meaning very. In this case, any member of the initiative would be considered HELA-compliant (read: very compliant).

CONCLUSION

The information contained within the report should be seen as an informed starting point on the journey to achieve a healthy and sustainable environment surrounding large-scale outdoor live events. Key questions have been raised, stemming from conflicting conclu-

sions in previously published research, pointing to numerous required areas of further research, spanning many different disciplines. The authors of the report plan to contribute to the highlighted necessary research, but a sustained effort by many individuals and organizations is required to adequately address each of the questions and satisfy the corresponding research needs. Due to the lack of coherent and consistent regulations world-wide, it is up to the audio and acoustics community to establish good practices and lead the way.

Discussion and feedback on the points raised in the report are welcomed and encouraged. This can be through meetings of the Audio Engineering Society Technical Committee on Acoustics and Sound Reinforcement (AES TC-ASR), held at every AES convention, or by contacting this report's primary author, Adam Hill (a.hill@derby.ac.uk). Regular updates will be published on the AES TC-ASR webpage [5] and through panel sessions at AES conventions.

The working group hopes that the report will spur a well-informed and sustained discussion and debate focused on the best ways forward. We hope the live event sector will embrace and support local communities to help them grow their local economies, protect their residents from harmful effects of sound exposure and noise pollution, and deliver awe-inspiring (but safe) experiences to audiences at outdoor events.

REFERENCES

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