MONICA, a European project focused on the Internet of Things for the acoustic quality and safety of outdoor large scale events

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ABSTRACT

Major outdoor cultural events are often accompanied by difficulties related to acoustic quality and safety. The European MONICA project (29 partners, H2020 funded) proposes to develop an integrated solution using connected objects to facilitate their implementation and quality for spectators, residents and organisers. This article proposes a presentation of the problem and the first results concerning the diagnosis of the noise exposure of neighbourhood and participants during two major events (Fête des Lumières and Nuits Sonores, Lyon, France; KAPPA FuturFestival and Movida, Torino, Italy). The diagnosis incorporates the physical assessment of noise and the perceived assessment of the soundscape by residents. It will also present the connected solutions envisaged for both acoustic control and participatory citizen feedback (perceived hindrances, perceived

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quality). The acoustic control system consists of components that can estimate and mitigate noise annoyance for neighbours during outdoor musical events. In this regard, a set of sound level meters using an IoT platform will be distributed in the venue and in the neighbourhood. The noise mitigation will be performed through an Adaptive Sound Field Control System, consisting of loudspeaker arrays with an adaptive model that adjusts for changes in climate and audience configuration.

1 INTRODUCTION

According to the United Nations, by the year 2050 66% of the world's population will live in cities[1]. Dealing with such continuous increase in population is a constant and challenging process for cities where important topics like security, liveability, well-being, infrastructure - just to name a few – have to be put in balance.

In this paper we will discuss a topic which is becoming more and more important as cities strive to be culturally diverse and offer to their citizens manifold cultural opportunities such as concerts, markets, festivals, sports events, etc. While such events offer great joy to one part of the citizens, i.e. the visitors, they also can mean a disturbance for citizens living close to such areas. A city has to consider both groups.

The large-scale pilot project MONICA (http://www.monica-project.eu/) tries to address the issue of having enjoyable events on the one side and keeping the noise pollution to a certain limit on the other side. The project demonstrates IoT solutions that allow event organizers to provide to their audience the best acoustic quality, while at the same time reducing noise annoyance for neighbours. Our approach to sound diagnosis is presented, aiming at creating awareness of the noise pollution during events. We present initial results of both sound monitoring and control at four events, the "Fête des Lumières" and the "Nuits Sonores"in Lyon, France and Movida ans the Kappa FuturFestival in Torino, Italy.

2 CONTEXT AND BIBLIOGRAPHIC ELEMENTS

Unlike research on the sources of noise from transport or industrial noise, or even those concerning enclosed places broadcasting music, there are relatively few recent publications on the acoustic impact of outdoor musical and cultural events.

In a 2005 publication, Sloven[1] describes the low frequency noise (LFN) issues associated with outdoor festivals based on experience in the Netherlands and Belgium:

"These festivities often take place at weekends and also run into the night. They are held in the open air and the heavy bass beat and rhythm gives rise to LFN audible over considerable distances. More and more of the organisers are becoming aware that the lower frequencies are very important in terms of disturbances."

"Local authorities are […] conscious of the importance of the weighting problem in measurements. LFN is being recognised as a significant issue."

It therefore reports on how local authorities are becoming increasingly aware of the limitations of the use of A-weighting (dB(A)) in assessing noise levels to which local residents are exposed during outdoor music events. Indeed, acoustic indicators based on A-weighting do not always adequately reflect the risk of annoyance caused by amplified music because they take little account of the low frequency content specific to this type of sound source.

Although several European countries have established criteria for the assessment of low frequency noise (Germany, Sweden, Denmark, the Netherlands, Poland[2] and more recently

France in the new decree on places broadcasting amplified music), current national regulations generally remain focused on the assessment of dB(A) levels.

Furthermore, concerning the current criteria for the assessment of low frequencies, Leventhall[3] underlines certain limitations (of low frequency indicators) related to the influence of fluctuations in noise levels on the expressed annoyance:

"Low frequency noise specific criteria have been introduced in some countries, but do not deal adequately with fluctuations."

Taking low frequencies into account is therefore likely to improve understanding of the perceived annoyance, compared to weighted indicators such as dB(A). Taking fluctuations into account should also make it possible to improve the description of low frequency phenomena.

In Sweden, Bengtsson and Waye[4] interviewed 37 Swedish local Environmental Health Authorities (EHA). The aim is to evaluate whether the specific guidelines on low frequency noise, adopted in 1996, were used and how they performed when assessing low frequency noise.

The results show that:

- Amplified music was one of the main noise sources related to complaints of low frequency noise (18% of complaints, just after fan and ventilation installations with 21% of complaints)
- When assessing low frequency noise, 62% of the EHA reported that the specific guidelines on low frequency noise based on third octave band analysis performed better or much better compared to the previous A-weighted guideline.

On the other hand, other authors[5], in a review of available data on entertainment noise from pubs and clubs, determined how a rigorous UK method for assessing it might be devised. Candidate assessment methods are identified, including those for general low frequency noise. Seven factors are identified which may affect the magnitude of the recorded subjective response: sound level, background level, differences between listeners, the context into which the sound intrudes, music type, bass level, bass beat.

In terms of subjective criteria used for validation of a new rating method, the authors state that "acceptability" (adjust the noise to a just acceptable level) should be a good compromise within "annoyance" (vary widely between individuals, large subject group needed) and "audibility" (more reliable measurement than annoyance but being a too strict criterion).

This article will therefore present an initial acoustic state, based on three complementary approaches: acoustic measurements, perception surveys and sound recordings, during the first editions of these public events. However, even if at this point in the project, not all acoustic indicators have yet been defined and calculated, sound level spectra are provided.

Based on these initial diagnostic elements conducted during the first year of the project, this article will present the main support solutions that will be developed and tested during the third year of the project. Indeed, the MONICA project aims, among other objectives, to propose the necessary tools for both diagnosis and assessment of perception (for users, organisers and residents) as well as solutions to be implemented in order to limit the negative acoustic impacts on users and residents.

3 FIRST ACOUSTIC DIAGNOSIS

This article therefore proposes a first inventory of the acoustic components at the end of the first year of the project, based on the work conducted by Acoucité on two project partner territories: the cities of Torino (Italy) and Lyon (France). To date, in these two territories, four major public events have been selected as experimental sites for the MONICA project.

3.1 Kappa FuturFestival, Torino, Italy

The **Kappa FuturFestival** is an electronic music festival that takes place every summer at the beginning of July in Dora Park in Torino, Italy. The festival runs from noon to midnight for two days (Saturday and Sunday) on three stages and welcomes 12,000 spectators per day.

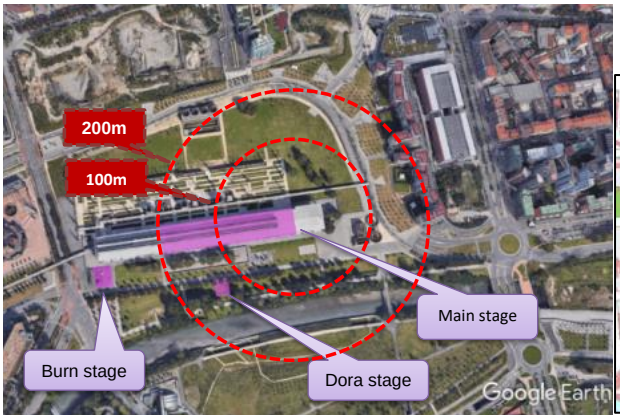

Fig. 1 – The three stages of KFF's venue

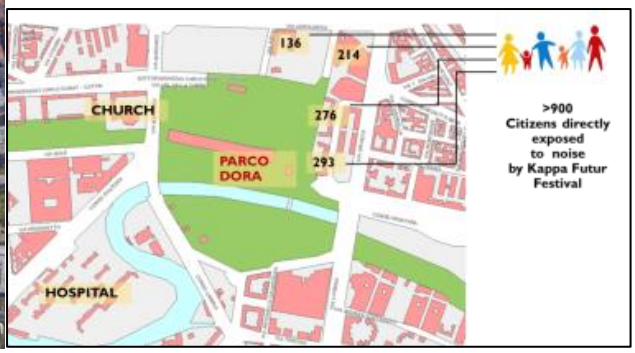

Fig. 2 – Closest dwellings and inhabitant's number

The Dora Park covers an area of 450,000 m². Close to the city centre, this urban park highlights the industrial past of Torino. One of the festival's distinctiveness is that it takes place in open air, in an urban environment, with dwellings. 900 residents are directly exposed (see Fig. 2).

Acoustic measurements were made using two approaches:

- Monitoring points, at residents' homes (throughout the festival)
- Short-term measurements points, coupled with audio recordings, on public spaces outside the site, as well as within the festival venue

Figure 3 shows all the measurement points.

Fig. 3 – Monitoring and recording points at KFF, Torino (in yellow)

The first measurements were aimed at assessing the noise levels of exposure of local residents around the festival site and comparing with the regulatory threshold (according to the Italian standard): LAeq (1 hour) < 70 decibels (A) (building facade).

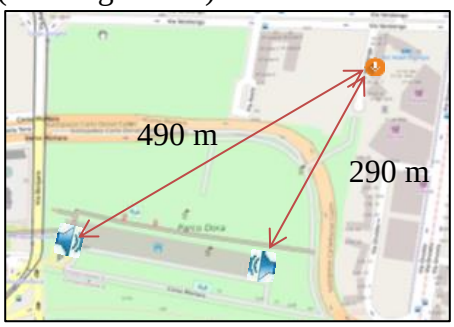

Fig. 4 – Location of sound level meters

Table 1 – LAeq in a local resident home

	LAeq (12h-00h)
07/07/2017	54
08/07/2017	68
09/07/2017	68

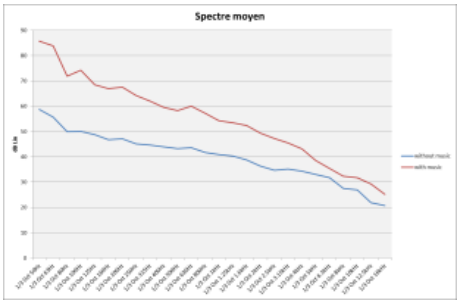

Fig. 5 – Periods with and without music, in dBLin

The results of the measurements show that the regulatory threshold of 70 dB(A) (table 1) is respected but that low frequencies have a strong contribution to the spectrum of the event (fig. 5).

Their main objectives were: 1) to assess noise exposure of the users (spectators, organisers, artists) by measuring the sound levels at different points inside the venue, 2) to design a map describing the soundscapes and sound levels, and 3) to supply the data base needed to develop source recognition algorithms with sound recordings. The sound recordings and part of the results of the measurements can be consulted on:

http://www.acoucite.org/cartes/2017-KFF/KappaFutur-EN.html

3.2 The Movida, an area of regular night-time activity, Torino, Italy

The Movida in Torino is located in the district of San Salvario and gathers a large number of party places (bars, pubs, restaurants, etc.) with a strong night activity inside and in the vicinity.

Sound recordings were made in May 2017 to design a soundscape map of the San Salvario neighbourhood, describing the contrast between the daytime and night-time soundscapes. The recording points were divided between the public space and the interior of the dwellings.

Closed window = 44 dB(A)
Open window = 62 dB(A)
On the balcony = 70 dB(A)

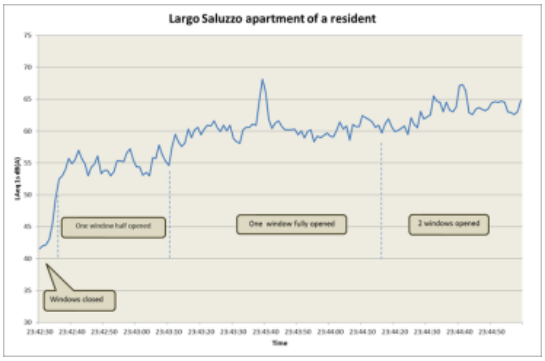

Fig. 6 – Example of a measurement taken (Thursday evening at 11:45 p.m. by a local resident)

On this site, tests were conducted to evaluate the relevance of using the Harmonica[6] index. It was developed for a previous European project, in order to give a more comprehensive view for local residents of the contributions of the background noise and the noise peaks that emerge from it. This index is currently more orientated towards the characterisation of transport noise. A comparison with perception would be necessary to conclude if this index (or a modified version of it) can be relevant to assess noise annoyance for such events.

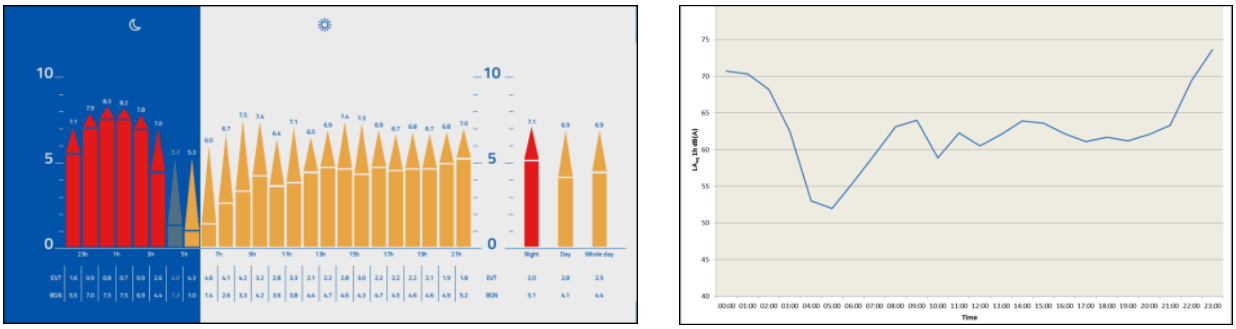

Fig. 7 – Harmonica index calculated for the square Saluzzo, Torino

3.3 Fête des Lumières, Lyon, France

Fête des Lumières is a free cultural event hosted by the city of Lyon. It is a festival composed of light installations with, for some of them, sound animations (four or five days at the beginning of December, from 8 p.m. to midnight). The audience is diverse, e.g. young people, families, elderly people, inhabitants of Lyon, tourists, etc. This site welcomed approximately 2 000 000 visitors in 2016.

An acoustic measurement campaign was conducted at Place de Terreaux in order to characterize the sound environment during Fête des Lumières. Measurement points were located as shown here below.

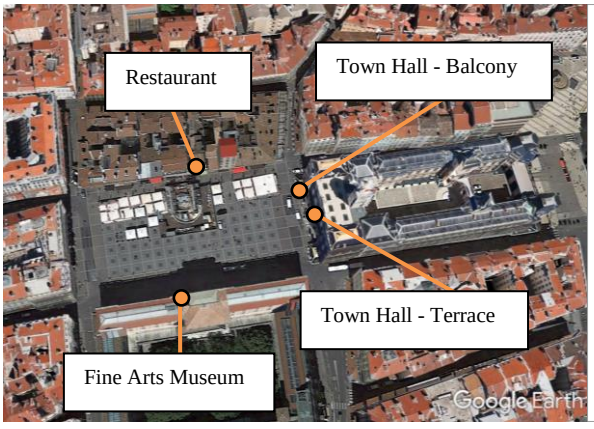

Fig. 8 – Long-term measurement points

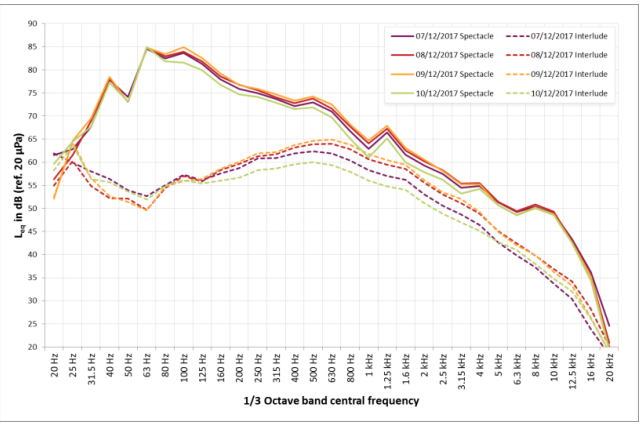

Fig. 9 – Sound level spectra at Town Hall - Balcony

The noise levels observed during Fête des Lumières were compared to those of the week before the festival. During show hours, sound levels were found 12 dB to 16 dB higher than those

measured the week before the show, within the same period of time. This difference in level is much less noticeable outside the show period.

Figure 9 shows sound spectra measured at one of the nearest buildings façades (Town Hall – Balcony). We can notice an important amount of sound energy in low frequencies. The comparison of the sounds measured during the broadcast of the show and during the interlude (crowd sound) revealed differences, particularly in terms of spectral composition. The sound during the performance shows greater amplitude than that measured during the interlude across the entire audible frequency range. However, the differences are much more pronounced for low and medium frequencies. Differences in sound dynamics were also noted. Indeed, the sound during the show's broadcast has a much greater dynamic than that of the interlude.

3.4 Nuits Sonores, Lyon, France

Nuits Sonores is a paid cultural event taking place in the city of Lyon. It is a festival that dives in the world of design, image, graphic art, food culture, architecture and particularly music.

This event is once a year for five days and five nights, in May from 5 p.m. to 5 a.m. (day and night events take place on different sites). The attendance is about 14,000 visitors at night and 6,000 visitors the day (for the 2017 edition).

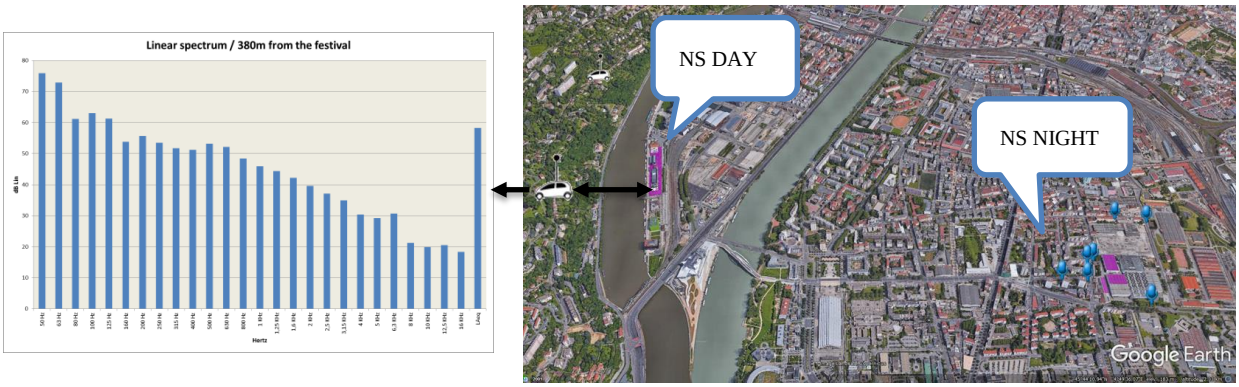

Fig. 10 – Measurement points location and linear spectrum of a daytime measurement point

Example of daytime measurement, less than 400 meter from the festival: this measurement point is 380 meter away from music sources (see figure 10). The A-weighted average sound level is equal to 60 decibels (A) over 30 minutes. The graph upwards is a representation of the average linear spectrum. The contribution of low frequencies remains important despite the distance and the various obstacles (buildings, roads, plants, etc.).

Example of night measurement, less than 40 meters from music broadcasting sources and 20 meters from local residents' buildings: the A-weighted average sound level is 70 decibels (A) over 55 minutes. The low frequency contribution has been demonstrated through measurements. Another aspect of the observations is the ongoing nature of their contribution. The image below is a sonogram calculated over the same 55-minute period. It shows elevated low frequency levels almost continuously.

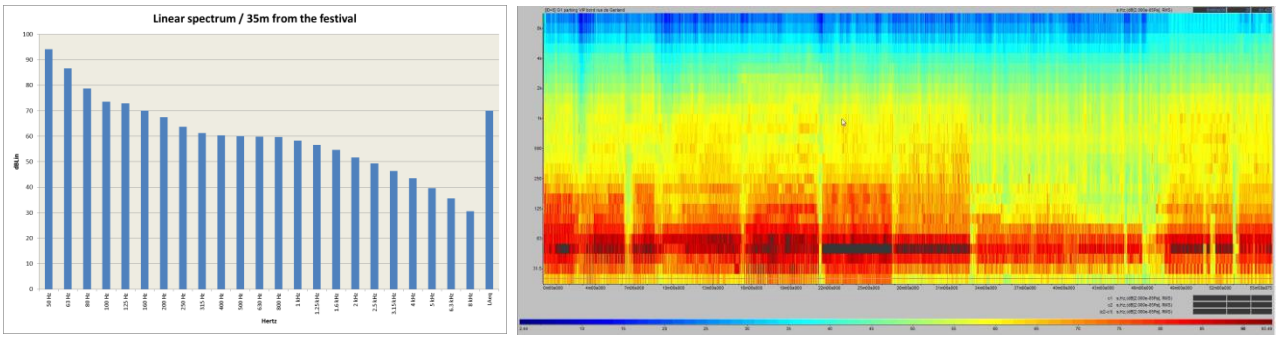

Fig. 11 – Linear spectrum and sonogram calculated for a night measurement point

3.5 Acoustic measurements, key learnings

Measurement campaigns conducted in particular to characterise the noise environment in resident areas during the Kappa FuturFestival 2017 (Torino) and Fête des Lumières 2017 (Lyon, Place des Terreaux) showed sound pressure levels that can reach levels between 75 dBA and 80 dBA on the facades of the most exposed buildings. For the Movida 2017 and Nuits Sonores 2017, sound pressure levels at the resident facades are up to 70 dBA. Differences on measured sound levels can be explained by variation from one case to another (nature of sound source, closed/opened venue, distance from source to receiver, etc.).

Regarding the frequency distribution of sound energy, we can observe that, while Kappa FuturFestival, Fête des Lumières and Nuits Sonores have high sound energy in the range of 20 Hz to 250 Hz, this is not the case for the Movida. This can be explained by the nature of the main sound source of this site: non-amplified human voices.

3.6 The perception survey

This questionnaire focuses on the perception of residents of the public events at the pilot sites. It focuses on their perception of music and noise related to these cultural and festive events. It was pretested before in Lyon (5 interviews and a reviewer).

This first field test was carried out in Torino during the KAPPA FuturFestival in July 2017 in collaboration with the city of Torino (Italy). In particular, the questionnaire and the procurement methodology to be adapted for each event was validated.

The average age of the respondents (128 persons) is 46 years and they have been living in their dwellings for an average of almost 10 years. The dwellings were located between the ground floor and the 18th floor (average floor =5) and are on average less than 500 meters from one of the stages of the festival. Nearly 2/3 of the respondents have a straight view to the festival location, 10% from their bedrooms and 28% from both their bedroom and another living room. A quarter has another room towards the festival without the bedroom. A total of 64% of the respondents therefore have at least one room in open field towards the festival.

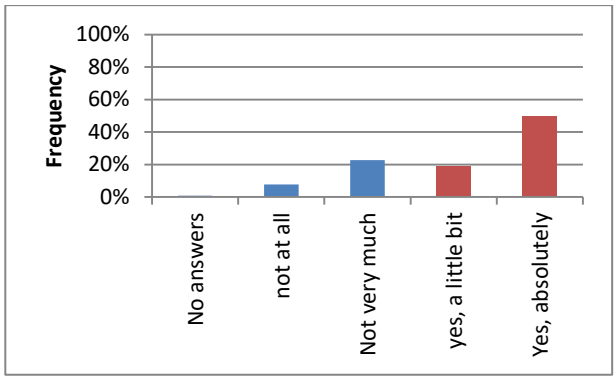

Fig. 13 – Do you think this event creates annoyance and discomfort for your home?

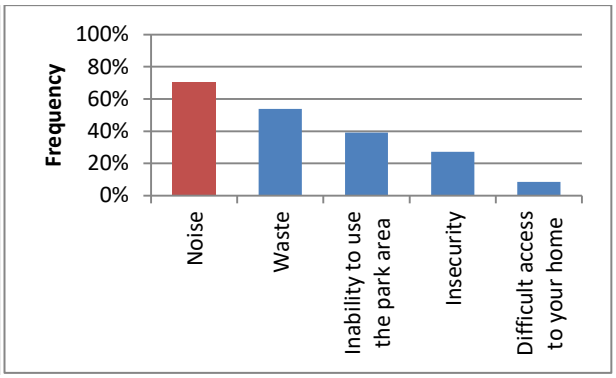

Fig. 12 – If so, for what (more than one response allowed)

The festival represents a strong or moderate nuisance for the local residents. This nuisance is mainly related to noise, waste, inability to access to the park during the festival and insecurity. To the open-ended question "what is the most relevant in your opinion?" Noise is the only response with a significant score (54.7%) followed by waste (10.9%) and park inaccessibility (6.3%). Other items with scores below 4.

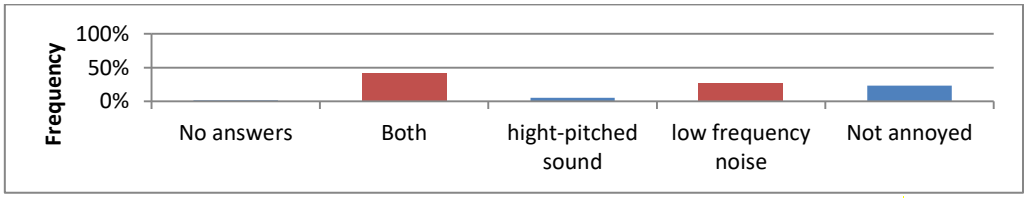

Fig. 14 – What are the sounds that annoy you the most?

The discomfort felt by residents is as much related to bass as high frequencies for 42% of respondents. According the sum of the answers:

- 47.7% of the respondents are bothered by high frequencies
- 69.5% by low frequencies

There is a statistically significant difference (F- Test = 3,072 p=.05) in the estimated distance between the dwelling and the stage, and annoyance: Respondents who report that they are not annoyed are, on average, at an estimated distance of more than 575 meters from the scene. Respondents who say they are constantly or often annoyed are living, on average, less than 406 meters from the scene.

These first results highlight particularly well:

- A nuisance felt by 3/4 of the residents who responded to this questionnaire;
- An annoyance associated with noise for more than half of the respondents;
- A predominance of low frequencies in the emergence of this discomfort.

3.7 Soundscape maps

Soundscape maps are digital tools developed by Acoucité, notably as part of its pedagogical and patrimonial activities. Their aim is to illustrate and integrate the sound recordings of an event or a place. Their particularity stems from the location of the sound recording on a map, therefore the use of the wording

Fig. 15 – Screenshot of soundscape map of Fête des Lumières 2017
http://www.acoucite.org/cartes/2017-FDL/MainLocations-EN.html

"soundscape map". Indeed, a practice of the sound recording is to be able to represent a soundscape[7] with the help of its hearing memory. The last developed map offers to discover the normal soundscape (without the event) of the main locations of the Fête des Lumières 2017. This soundscape map allows mixing several evaluation information related to sound environment into the same medium: exposure of populations, sonometric measurements, sound recording, and written description of the recording.

4 SOUND MONITORING SYSTEM

The sound monitoring system consists of a set of IoT Sound Level Meters (SLM), sending data to the MONICA IoT Platform.

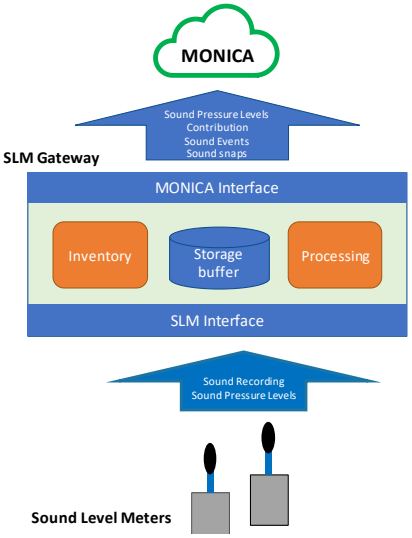

Fig. 16 – Overall Sound Level Meter Concept

Acoustic levels and recordings are transmitted to a SLM Gateway which takes care of local buffering, data analysis/reduction and communication with the MONICA Cloud. The concept is illustrated below. In addition to acoustic levels and audio recordings, the system will provide more advanced information, useful in the context of large outdoor events.

One useful information is the noise contribution of the event in the neighbourhood. For this purpose, a set of IoT sound level meters will be placed in the vicinity of the outdoor event to monitor the noise levels. However, the measured level will receive also contributions from other noise sources such as traffic. Therefore, the measured noise might not be representative of the event.

The contribution analysis corrects the levels to get an estimate of the true contribution from the venue. At this stage, different approaches are considered. One based on a coherence method which extracts the audio signal that is coherent with recordings close to the stage. Another approach is based on machine learning, where we identify music sections from the audio signals recorded by IoT sound levels meters in the neighbourhood.

Another useful information is the detection of unusual events related to security, based on audio recordings. The SLM Gateway can be trained to automatically detect specific events from the recorded sound, like gun shots, screaming people and accelerating cars. This type of information can be fused with other data that are sent to the MONICA cloud, such as video streams.

5 CONCLUSION

These initial results indicate the importance of the low frequency issue at metrological and perceptual levels, already clearly identified in the publications of the early 2000s. Little normative or regulatory work seems to have actually been conducted in recent years on low frequencies in the environment generated by amplified music, except on the noise of wind turbines.

In view of the initial elements analysed, it seems particularly relevant to take into account on the one hand the low frequency content and on the other hand the fluctuations in levels with regard to the assessment of noise (noise monitoring).

For this, in addition to the classical indicators (sound pressure levels) additional acoustic indicators such as pressure level spectra or levels in a particular frequency range (i.e. 0-250 Hz) will be tested. Other indicators such as the Harmonica index[8] and psycho-acoustic indicators (i.e. loudness) will also help to better translate the discomfort/perception expressed by taking into account low frequency content, as well as fluctuations in levels and sensory dimension.

By the end of 2019, the MONICA project will provide a set of tools, methods and indicators to improve the consideration of sound in outdoor cultural events, both for users (spectators and organisers) in a public health approach (noise exposure), and for local populations (noise annoyance). Indeed, on the acoustic part, the next 18 months will be dedicated in particular to development and design of:

- the IoT platform to collect all the useful information for a management in real time of the acoustic field;
- acoustic control solutions to minimise exposure of local residents and sensitive groups (e.g. in first aid areas);
- mobile applications (smartphones) enabling real-time collection of perception (professionals, spectators, local residents) and information for users on their potential exposure.

The MONICA project will offer an integrated solution to bring safety and acoustic comfort to large scale events for spectators, organisers and residents.

6 ACKNOWLEDGMENTS

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