

Research Article

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Noise monitoring in Monza (Italy) during COVID-19 pandemic by means of the smart network of sensors developed in the LIFE MONZA project

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Abstract: As a scientific consequence of the spread of the COVID-19 pandemic, several initiatives have taken place in order to monitor noise levels trends before and after the lock down phase in several Italian and European cities. In Monza (Italy), since June 2017, a new smart noise monitoring system consisting of 10 sensors developed in the frame of the LIFE MONZA project is continuously measuring acoustic data every second and transmitting them hourly to a dedicated server. The sensors are located both along a main street of the Libertà district characterised by high traffic flows and along secondary streets of the district; they are positioned on (preferably sensitive) buildings facades and on streetlamps.

In the present paper results of a study concerning changes occurred in noise levels trends before and during the lock down phase for the smart sensors are presented, together with a comparison with noise levels collected by the same sensors in the equivalent months of the previous year. Some preliminary considerations regarding the reliability of the sensors themselves are also provided.

Keywords: noise mapping, noise monitoring, smart network of sensors, LIFE MONZA

1 Introduction

The COVID-19 pandemic spread in Europe after a few months of appearance in China and in the Far East countries. At the beginning, nobody would have imagined the wide consequences of it in people's life. The virus had terrible consequences on people health (10.458,422 cases con-

firmed worldwide after five months since the beginning of the epidemic and 511.082 dead [1]) and several governments and public authorities reacted worldwide introducing serious restrictions to contain the phenomenon, from closing public areas to total lock down. Regarding other politics of fight against the propagation of the COVID-19, the social distancing protocol was established in the most part of the World.

In this critical scenario, some positive effects were also observed during the virus propagation. From the environmental point of view, the lock down can be considered as a long mobility week: few cars in the streets as well as reduced shipping and flight activities led to a significative benefits for air quality and road traffic noise emission in cities. Due to the effect of the total stop of passenger road traffic, the reorganization of public transport facilities and the sustainable transport communities the CO₂ emissions have dropped by 58% across Europe [2]. The “no emission” level targeted for the far future was reached involuntary, which would be the halfway to the 2050 net zero goal in case the current people behaviour is maintained in the future.

Regarding noise, nearly 80% of the European population lives in urban areas (where pollution effects are more significant) and is exposed to high or extremely high noise level. Road traffic noise emission is one of the most important factors influencing urban population everyday life [3]. Noise is defined as an unwanted sound and road traffic noise annoyance is the response of a person exposed to road traffic noise. The total road traffic noise annoyance is a sum of three components: subjective, objective and visual road traffic noise annoyance. The lock down related to the COVID-19 pandemic had some effect on all the three components.

In this period, the acoustics community is mobilizing in order to organise initiatives aimed at collecting acoustic data, in terms of noise levels trends and noise perception, to “record” this unique soundscape.

In Italy, the measures to contain COVID-19 infection implemented throughout the country since 11 March

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2020 (date in which the Prime Ministerial Decree of 11 March 2020 on further measures for the containment and management of the COVID-19 epidemiological emergency throughout the country was published) have led to a radical transformation of the soundscape that surrounds citizens and to which they are accustomed. As an example, the Acoustical Society of Italy (AIA) has organised two main activities. The first one regards the collection and analysis of data measured during the emergency through surveys obtained both from fixed and mobile monitoring stations (permanent control units, acoustic climate detection stations, etc.) and from "extemporaneous" positions at the homes of the participants in absolute compliance with all the provisions in force on the Italian territory for the containment of the epidemiological emergency. The second one concerns the design and online submission of a questionnaire aimed at evaluating people perception of the soundscape before and during the lock down phase. In addition to some initial questions of a general nature, 9 questions are related to the period before the Prime Ministerial Decree of 11 March 2020 and 9 questions are related to the lock down situation.

The Provincial Agency for the Protection of the Environment of the Autonomous Province of Trento (APPA Trento) shares the initiative to collect environmental noise levels during the emergency by COVID-19, launched by AIA, carrying out extensive monitoring over the provincial territory both to document the acoustic climate of the province and to assess the acoustic impact of the protection measures adopted during the health emergency.

As another example, in the city of Turin data from the noise monitoring network, managed by the City and Arpa Piemonte, were analysed to obtain a first quantitative evaluation of the acoustic effects induced by the restrictions in urban areas. The values acquired from 11 measuring stations were examined, 8 of which were aimed at detecting road traffic noise pollution and 3 at monitoring traffic noise in the San Salvario district. An average reduction in road noise of 5 dB was recorded, from which it was estimated a 70% reduction of the number of vehicles on the road, with significant effects also on the nightlife areas.

At the same time, new projects are active to collect recordings and metadata of sounds in the COVID-19 scenario. The LYS (Locate Your Sound) project [4] in Italy (about 4000 recordings at the beginning of July 2020) invites the citizens to spontaneously collect and record the soundscape during lock down near their places of life.

Acoucity has developed a questionnaire oriented towards assessing population feelings about the changes in the noise environment since lock down [5]. In London the UCL Acoustics Group is running an online experiment as-

sessing some recordings achieved in the pre- and during-lock down soundscapes [6].

In the USA, the N.Y.U. project, called SONYC, recorded audio clips from one of 16 microphones that have been monitoring patterns in noise pollution in the city for more than three years, in research funded by the National Science Foundation. The microphones are mostly located in Manhattan, with others in Downtown Brooklyn and Corona in Queens. The archive of years of recordings gives a clear sense of a citywide rhythm over time — in normal times. It turned out that April days in New York were quieter than a typical holiday. The rhythm of the week has disappeared, and nights have been especially silent.

As a sort of bizarre coincidence, 2020 has also been officially recognised as the International Year of Sound (IYS) under the UNESCO Charter of Sound No. 39C/59. IYS is a global initiative organised by the International Commission for Acoustics (ICA) to highlight the importance of sound in all aspects of life on Earth and will lead towards an understanding of sound-related issues at the national and international level. In the frame of IYS several activities, such as an international competition for students and various kinds of initiatives (workshops, concerts, exhibition, etc.) aimed at valorising positive sounds of the world have been organised [7]. Due to the spread of COVID-19, ICA decided to extend the IYS duration also to 2021. This means that organisers can decide to reschedule events originally scheduled for the 2020 in 2021 and they still be part of the IYS celebration. The decision regards also the postponement of the students' competition to the school year 2020-2021.

The present paper focuses on the analysis of noise data measured in the period prior to, coinciding with and immediately following to the lock down phase in Italy by the smart low-cost sensors installed in the Libertà district of the city of Monza (Italy). This prototype network of ten sensors was developed in the frame of the LIFE MONZA project. The aim is demonstrate that a complex phenomenon such as that of COVID-19 pandemic has important consequences also to noise levels trends which are expected to significantly decrease during the lock down phase if compared to the periods both before and immediately after and also referring to the same period of the previous year and that such a phenomenon can be effectively monitored also by a prototype, smart, low-cost noise measurement system.

In section 2 a brief overview of the LIFE MONZA project is made and some information about the prototype noise monitoring system is provided together with a description of periodic verifications carried out in order to test the system's reliability and with a focus on reliability checks car-

ried out on the smart network. In section 3 data collected by nine sensors in the first six months of 2020 and in the same period of 2019 are reported, whilst in section 4 obtained results are discussed.

2 The smart noise monitoring system developed in the LIFE MONZA project

2.1 The noise low emission zones and the LIFE MONZA project

The institution of a Low Emission Zone (LEZ) is a frequent and consolidated action in the administrative practice of European cities and the impacts and benefits concerning air quality are widely analysed, while the effects related to noise pollution have not been comprehensively addressed. A LEZ is an urban area subjected to traffic restrictions in order to ensure compliance with the atmospheric pollutant threshold values, set by the European Air Quality Directive (2008/50/EC). The definition, the criteria for analysis and the management methods of a "Noise Low Emission Zone" are not yet clearly expressed and shared.

The LIFE MONZA project (Methodologies fOr Noise low emission Zones introduction and management - LIFE15 ENV / IT / 000586), co-funded by the European Commission and concluded on 30 June 2020, is dedicated to these topics [8]. The main objective of the project, coordinated by ISPRA, is to develop and test a methodology, easily replicable and applicable in different contexts. This is crucial for the identification and management of the "Noise Low Emission Zone", an urban area subjected to traffic restrictions, whose impacts and benefits concerning the issues of noise pollution have been analysed and tested in the pilot area of the Municipality of Monza. The latter is one of the project partners together with the University of Florence and the Engineering Company Vie en.ro.se. In the pilot area, the combined effects on noise, air quality and health of residents have been jointly analysed. Further objectives of the project concern the definition of the type of interventions capable of inducing beneficial and synergistic effects with regard to noise pollution, such as those concerning the planning of traffic flows and the active involvement of the population in the definition of a different and more sustainable lifestyle. In order to contribute to the implementation of the European directives, avoiding overlapping, the potential synergies between the issues related to noise pollution and air quality, the investigating activi-

ties, the monitoring criteria, the methods of representation and, in particular, the mitigation and improvement interventions, related to the introduction of the Noise Low Emission Zone, have been probed and, where possible, made coherent.

One of the most significative aspects of the LIFE MONZA project was the design and test of a new smart noise monitoring system which began to measure noise levels in the area on June 2017 and, at the end of the LIFE MONZA project, is given for free to the city of Monza that will take care of using it for monitoring activities in the three years after the project conclusion.

2.2 Specifics of smart sensors

The low-cost smart sensors technical specifications were defined keeping in mind the aim of a long-term monitoring of acoustic parameters. These are expected to be useful to understand the variability of acoustic climate in the pilot area with mainly reference to the overall A-weighted continuous equivalent sound pressure level. According to the previous general requirements and to the outcome of the state of the art analysis described in [9, 10], the following main specifications of the monitoring units are defined and further detailed in [10]:

- acoustic parameters: overall A-weighted continuous equivalent sound pressure level, "LAeq" and continuous equivalent sound pressure level, "Leq", as 1/3 octave band spectrum data;
- timing for data recording: acquisition with a time basis of 1 second in order to permit the recognition of unusual events in the eventual analysis phase;
- timing for data transmission: data will be sent to the remote server every one hour;
- data transmission network: data will be transmitted through the 3G cellular telephonic network;
- power supply: small solar panel (30 cm × 20 cm) and battery for energy storage or direct connection to electricity network;
- sensors location: on streetlight or on façade, height 4 m above the ground level;
- floor noise: < 35 dB(A);
- frequency response at nominal frequencies of 1/3 octave within the class I specs ± 1dB.

Two types of microphones are used:

- for sensors placed on poles that use solar panel energy, in order to obtain these high performances of energy efficiency, digital MEMS microphones are used that do not require the use of an external ADC.

for the selection of measuring positions. From a practical point of view, ten monitoring stations have been installed in the pilot area of Libertà district, as illustrated in Figure 1. In particular, three microphones (hb101, T0014 and hb152) have been installed along the Viale Libertà, the main street where the traffic flow mix is expected to mainly change from ante to post operam scenario. The other microphones have been uniformly distributed along other streets belonging to the pilot area.

2.4 Periodic verifications

Concerning the verification procedures, the low-cost sensors challenge consists in maintaining the network performance during long term periods of outdoor operation.

The periodic check of the system is designed and performed to understand if the measurement accuracy is maintained in time or if one or more sensors need to be repaired or replaced [11]. After the preliminary check procedures were applied, the long-term on-site verification procedure has been applied both in the ante and in the post-operam periods to verify the noise monitoring system performances.

The long-term on-site checks are scheduled every four/six months at least for two years during the noise monitoring period in the pilot area (1 year in the ante-operam scenario and 1 year in the post-operam scenario). As on-site check activities, the following time-stability verifications have been performed every four/six months:

1. – 1 kHz calibration check: a calibration check at the frequency 1 kHz, requiring for long term check that the sound pressure level does not deviate more than 1.0 dB from the results of the previous calibration check. Calibration is performed by the operator

by inserting the microphone into a sound pressure class I calibrator. Given the position of the sensors at a height of 4 m from the ground, the activity requires an elevated platform or a ladder.

2. – Broad band check: a comparison between the LAeq,30s* obtained from the low-cost sensors and a class I equipment both subjected to the same broad band noise signal (e.g. pink noise produced by an electroacoustic equipment **) in the range 45/105 dBA by, requiring for long term check a difference between the two systems within 2.0 dB(A).

* This analysis also permits a check of low-cost equipment in different one-third octave band.

** For this analysis also road traffic noise is usable. In this case measurement time period is extended up to 5-10 minutes to be significant.

At the current time, eight on site checks have been performed: in July and November 2017, in March and July 2018, in January, May and December 2019 and in June 2020.

2.4.1 1 kHz and broad band checks

In Figures 2 and 3 results obtained periodically for calibration checks respectively for sensors placed on facades and on streetlamps are reported. On average, two/three checks were carried out per year starting from July 2017.

Concerning the calibration of the sensors placed on streetlamps, a 3 dB attenuation of the calibration noise levels on the MEMS digital microphones was observed in the first survey with respect to the second one; later noise levels became stable except for some fluctuations due to microphones breakages and replacements. As to the sensors

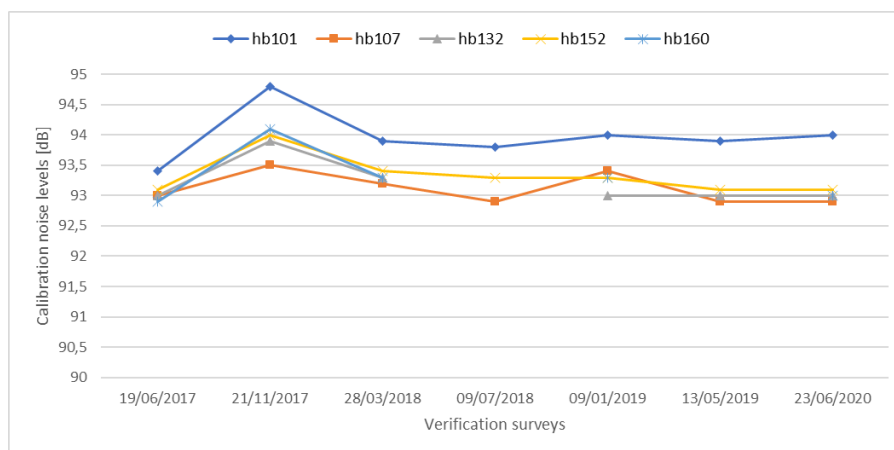


Figure 2: 1 kHz calibration check – Electret sensors placed on building's façades

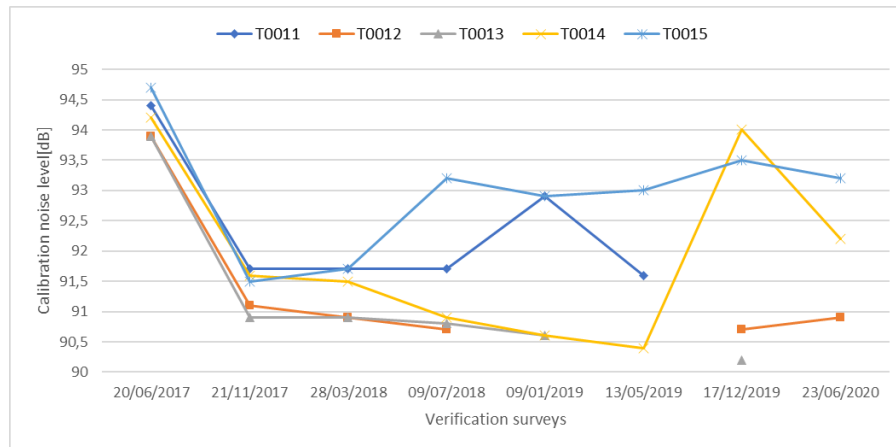


Figure 3: 1 kHz calibration check – MEMs sensors placed on streetlamps

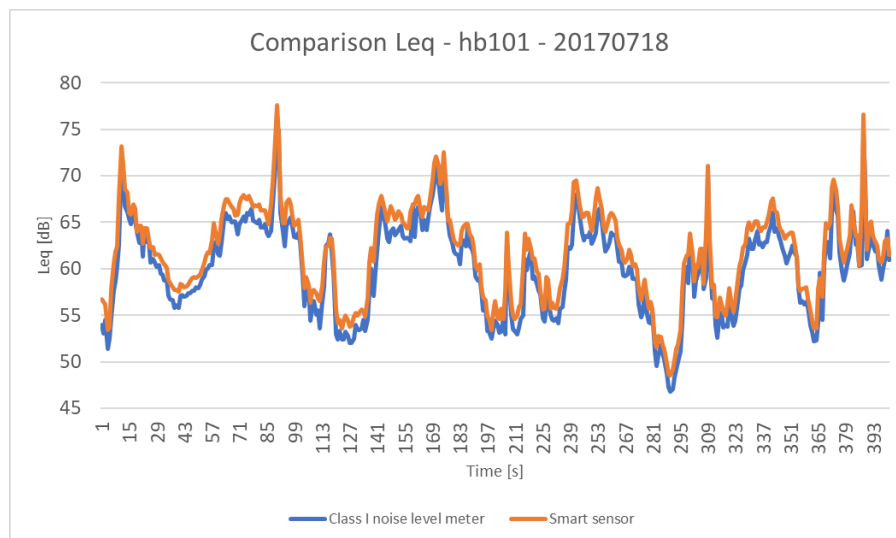


Figure 4: Broad band check (by using road traffic noise), considering 7 minutes as measurement time period – Time history of sound pressure levels, in terms of $LA_{eq,1s}$ [dB(A)]

placed on buildings' facades, noise levels have revealed to be more constant.

Therefore, for future applications of MEMS digital microphones, it is suggested to consider a “stabilization period” of about 2 months before low-cost sensors can be considered reliable.

Concerning broad band checks, results for noise measurements carried out by using respectively road traffic noise and electroacoustic speaker as noise sources are reported.

When road traffic noise is considered as the source, the measurement time period was extended up to 5-10 minutes. A difference of 1.5 dB(A) between the class I noise level meter and the smart system in terms of average LA_{eq} has been found by considering all the checked sensors. Higher differences, of about 2-2.5 dB have been encountered

with smart sensors placed on streetlamps, while smaller differences, of about 0.5-1 dB have been encountered with smart sensors placed on the façade. An example is shown in Figure 4.

Even a comparison in terms of sound spectrum has been made and an example is reported in Figure 5.

Concerning noise measurements carried out with the electroacoustic speaker, a pink noise signal was used and a measurement time period extended up to 30 seconds was established. In general, a difference of 0.5-1 dB(A) between the class I noise level meter and the smart system in terms of average $LA_{eq,30s}$ has been found by considering all the checked sensors. No significant differences have been encountered between sensors placed on streetlamps and on the façades. An example is shown in Figure 6.

An example of sound spectrum is reported in Figure 7.

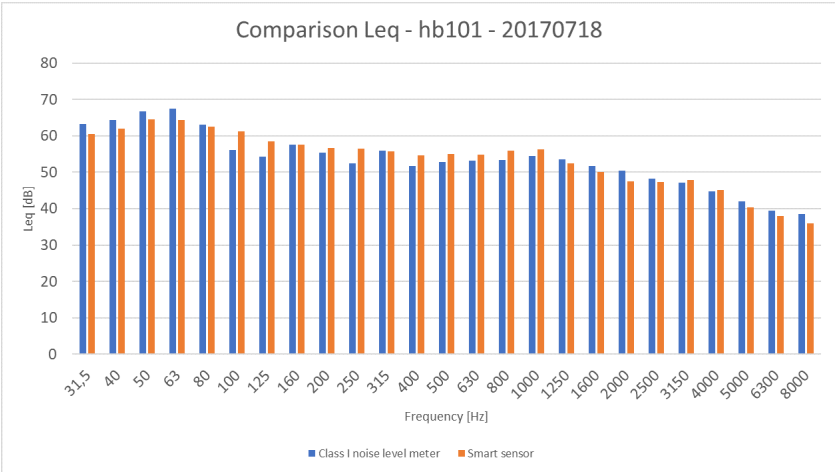


Figure 5: Broad band check (by using road traffic noise), considering 7 minutes as measurement time period – One third octave band sound pressure levels, in terms of $Leq,10'$ [dB]

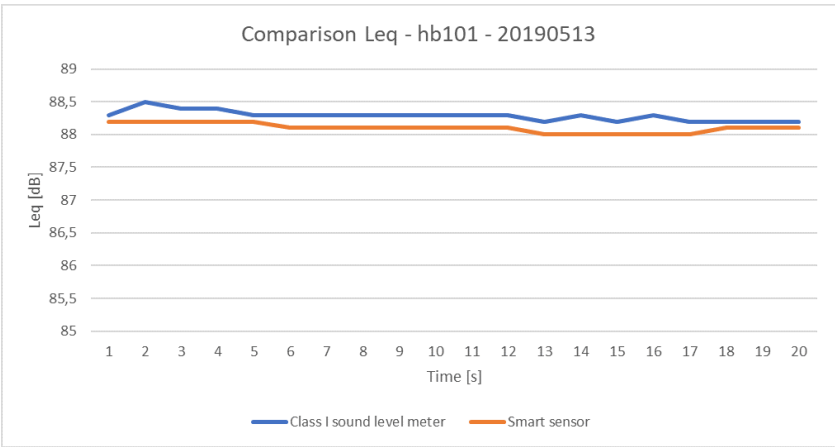


Figure 6: Broad band check (by using an electroacoustic source and a pink noise signal), considering 30 seconds as measurement time period – Time history of sound pressure levels, in terms of $LAeq,1s$ [dB(A)]

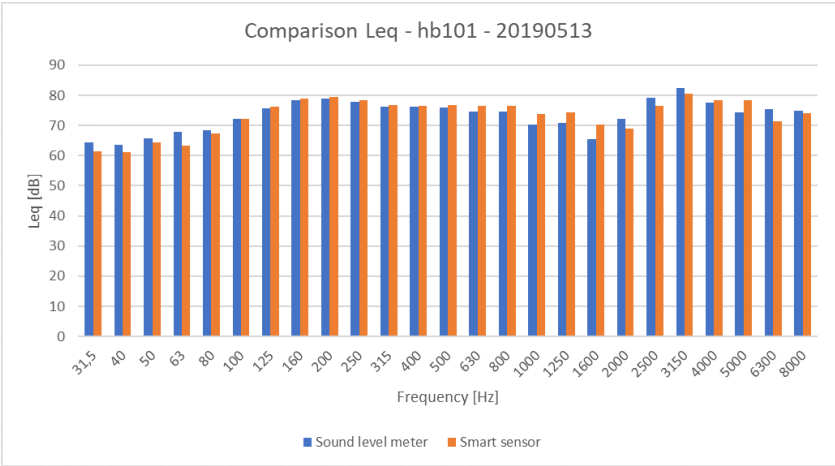


Figure 7: Broad band check (by using an electroacoustic source and a pink noise signal), considering 30 seconds as measurement time period – One third octave band sound pressure levels, in terms of $Leq,30s$ [dB]

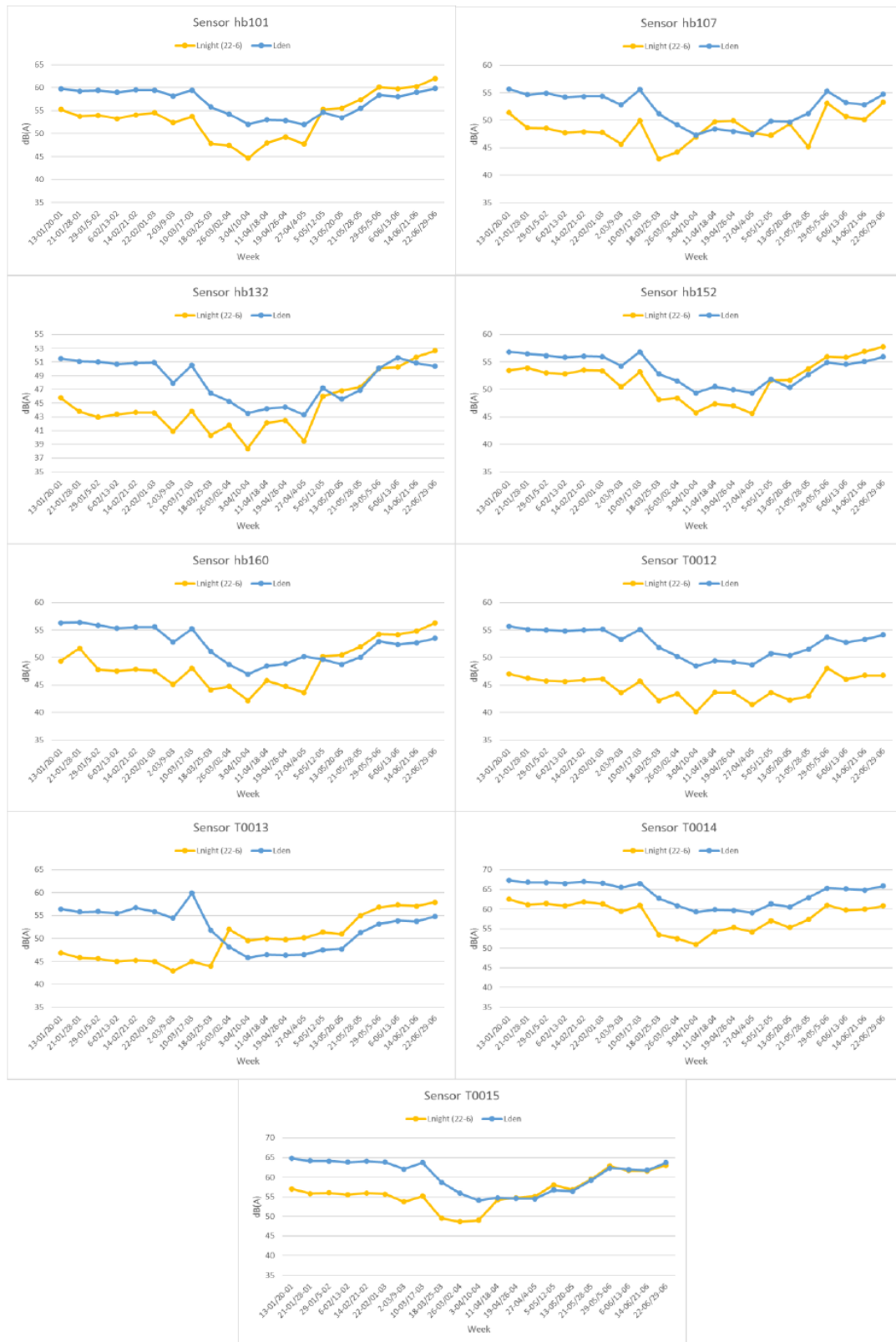


Figure 8: Lden and Lnight weekly values for the period from 13 January to 29 June 2020

Regarding sensors' stability during the COVID-19 period all sensors proved to be stable according to calibration checks performed before and after the lock down period.

Regarding the reliability of smart noise monitoring systems, a first important result consists in the verification of a good alignment between noise measurements carried out with class I sound level meter and the low-cost network, with average differences below 1 dB.

The usability of the smart noise monitoring system has been verified and supported by its more affordable cost.

Further results on comparing the measured results by traditional sound level meter and noise sensors obtained in the frame of the LIFE MONZA project are available on the project website [12].

3 Experimental results

In Section 3.1 data collected by each sensor in the period January – June 2020 are presented, in order to observe trend variations before, during and just after the lock down phase.

In Section 3.2 data collected in the same period but in 2019 are presented and compared with previous ones.

Data collected by the sensor T0011 are not included in the dataset since the related microphone has been subject to breakage during the considered period in 2019.

3.1 Data collected in 2020

Referring to the lock down period, in the city of Monza, starting from February 23rd the Municipality of the city of

Monza ordered the immediate activation of a series of measures, in full accordance with the indications of the Lombardy Region. Specifically, the freedom of movement for people was restricted for essential activities and in confined areas. Events or initiatives of any kind, all forms of meetings in public or private places, including those of a cultural, recreational, sporting and religious nature, were suspended. All schools were closed, including nursery ones; master's, professional courses and courses for the health professions were also halted, except for trainees. Eventually, museums, exhibition spaces, the Villa Reale, city libraries, cinemas, theatres and other places of culture were closed to the public. In order to avoid dangers for the most fragile users, the Municipality decided to close also the elderly and disabled day centres. The courses scheduled at the Civic City Centre were suspended, too.

Moreover, an even more marked decreasing trend is present after the entry into force of the National D.P.C.M. of 11th March 2020 that approved the closure of many commercial activities. A trend inversion is present since the entry into force of the National D.P.C.M. of 26th April 2020 that established the beginning of as the so named "Phase 2" since 4th May, partially relaxing the restrictive measures taken so far.

In Figure 8 the weekly average values of Lden and Night parameters obtained in the period from 13 January to 29 June 2020 of the 9 sensors are reported. The portion of the graph between the two grey lines is related to the lock down period.

The highlighted legislative phases are reflected in the noise levels measured by the sensors, as shown in Figure 9 with reference to sensor hb101.

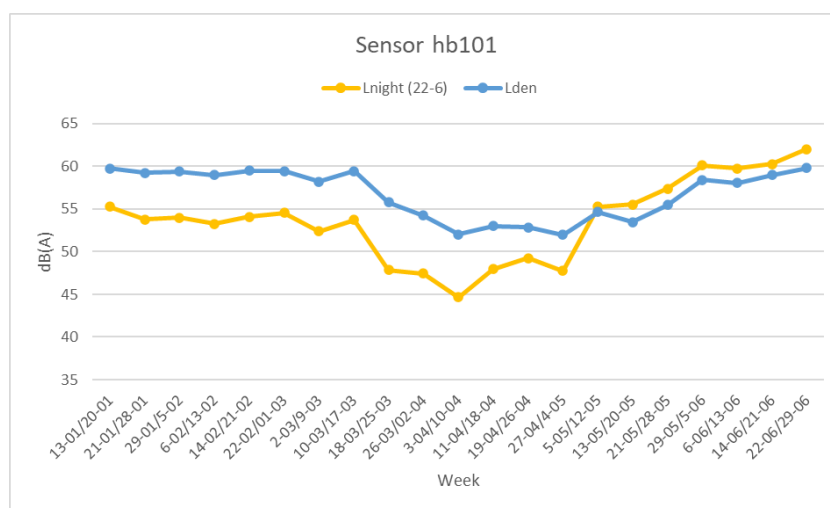


Figure 9: Emphasis on regional and national measures establishment against COVID-19

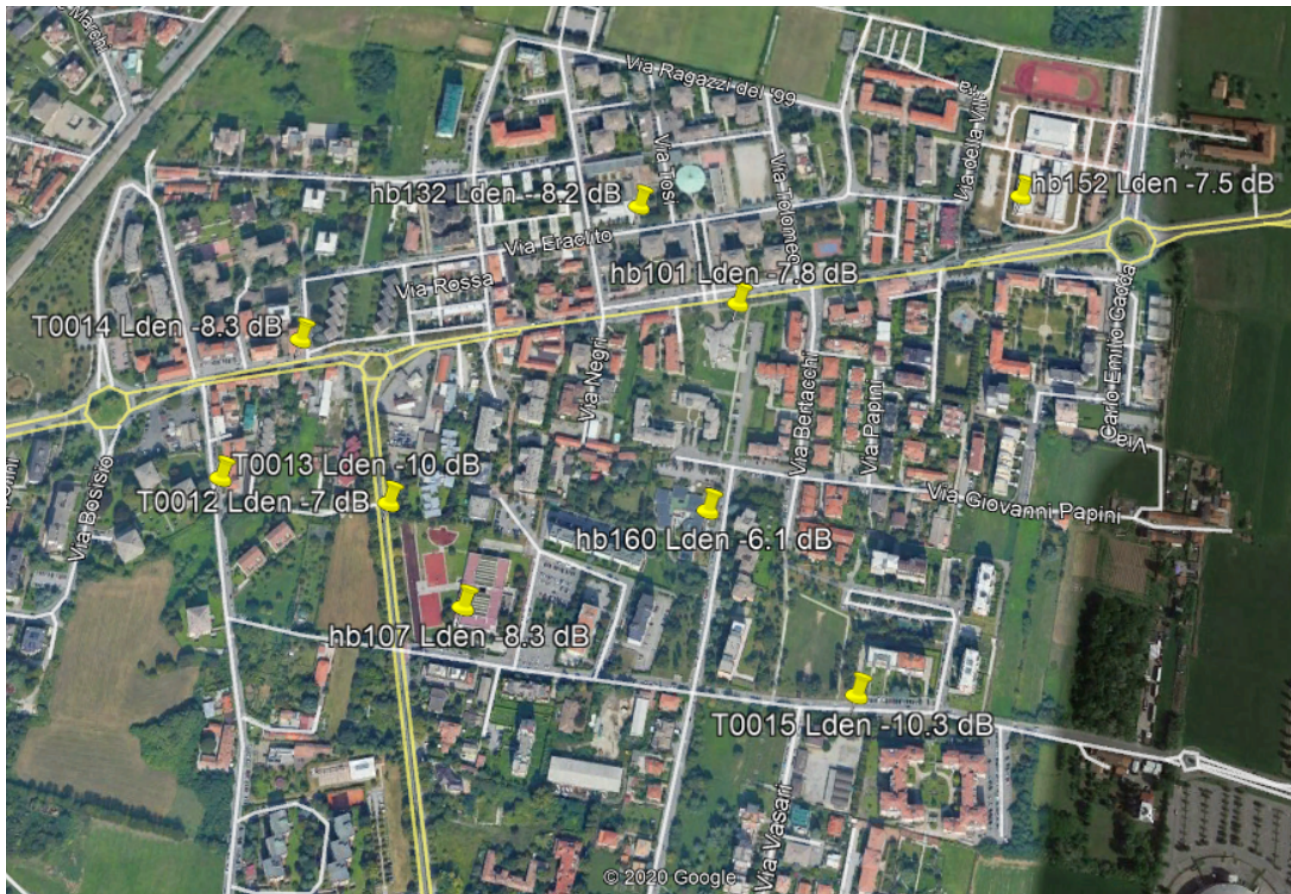


Figure 10: Lden reductions obtained for each sensor

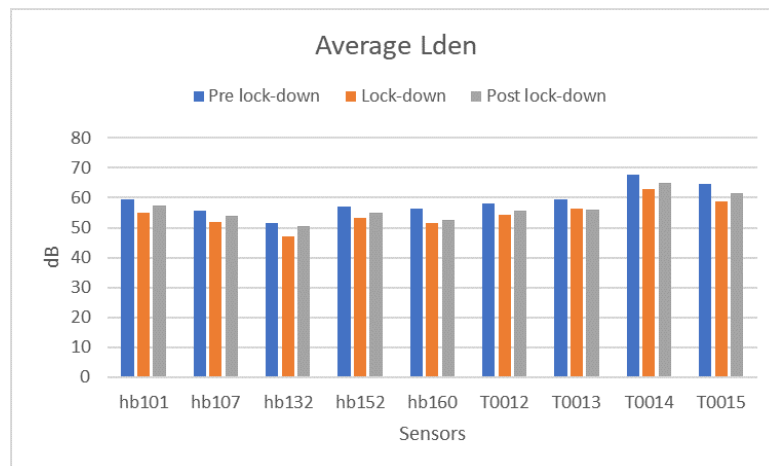


Figure 11: Average Lden for periods before, during and after lock down

In Figure 10, the noise level reduction evaluated according to the Lden parameter as difference between the first week of January and the last week of April is reported for each sensor.

Lden reductions are comprised between 6.1 dB and 10.3 dB.

In Figure 11 the comparison in terms of average Lden referred to the pre lock down period (13th January to 11th March), the lock down one (12th March to 3rd May) and post-lock down one (4th May to 29th June) for each sensors is reported.

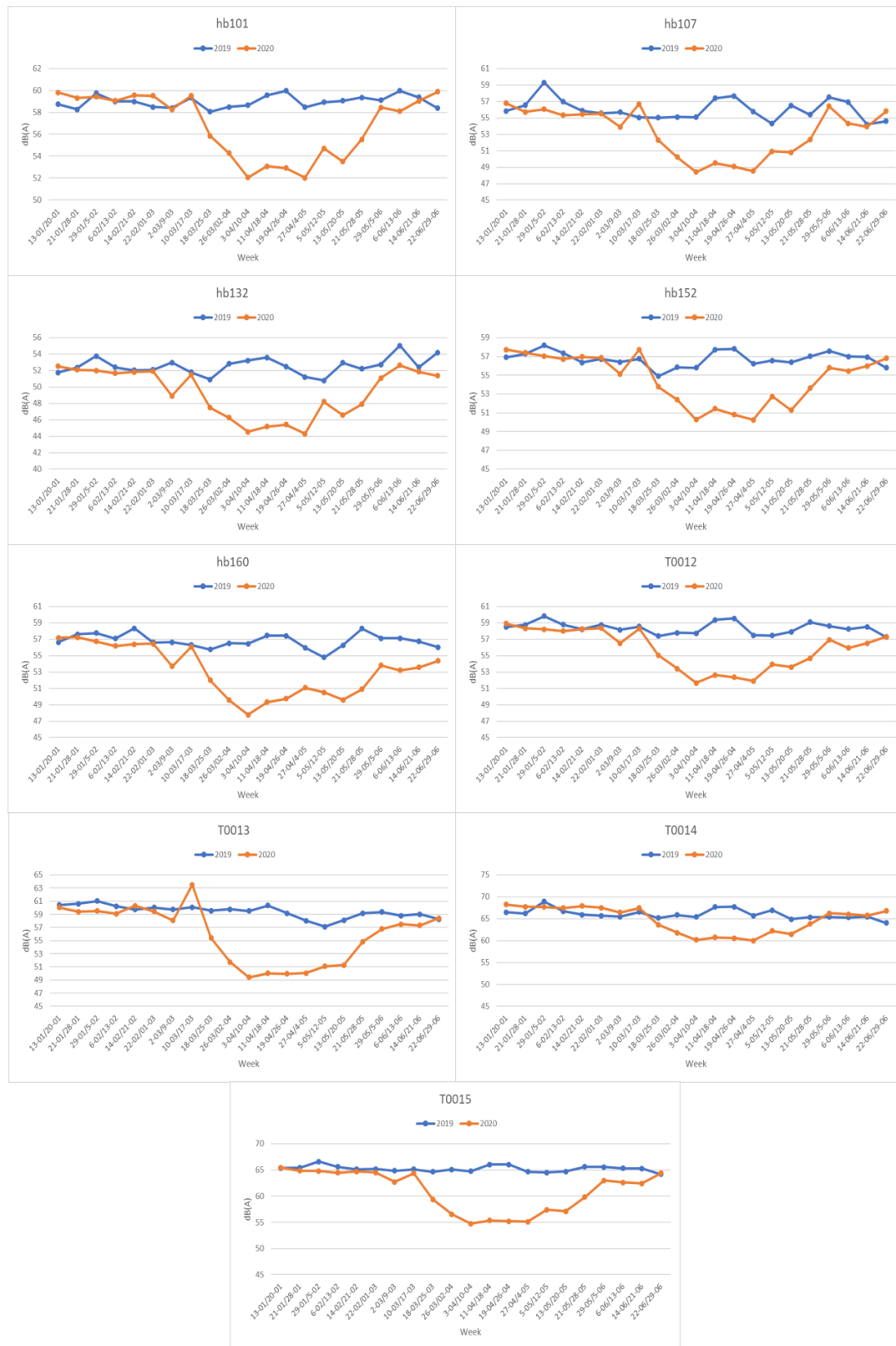


Figure 12: Comparison between weakly average L_{den} values for 2019 and 2020

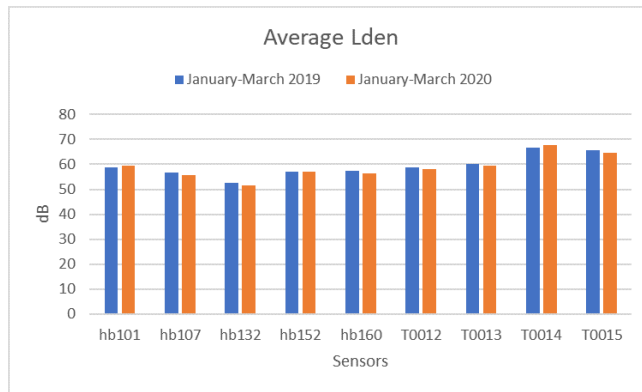


Figure 13: Comparison between weakly average Lden values for the period 13th January – 11th March of 2019 and 2020

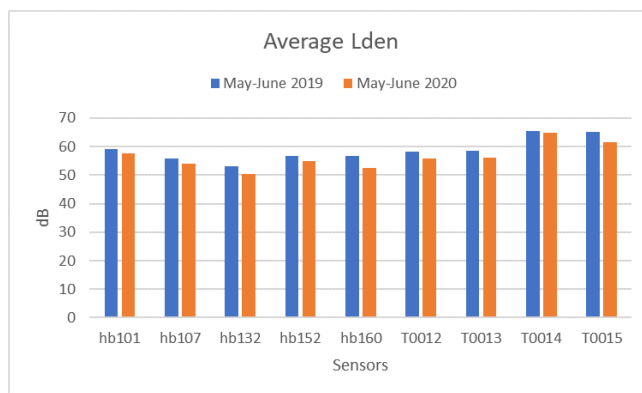


Figure 14: Comparison between weakly average Lden values for the period 4th May – 29th June of 2019 and 2020

3.2 Comparison between 2019 and 2020 data

In Figure 12, noise levels trends for the period January – June are compared referring respectively to 2019 and 2020 for each of the considered sensors. Specifically, weekly average values of Lden parameter are reported. It can be observed that the curves remarkably split apart in the lock down period.

In Figure 13, differences in terms of average Lden measured between January and April of 2019 and 2020 (so referred to the pre lock down period) are reported, whilst in Figure 14 differences in terms of average Lden measured between May and June of 2019 and 2020 (so referred to the post lock down period) are presented.

4 Discussion

Concerning the noise levels during the 2020 period, each sensor measured a marked reduction from the end of

February, due to the ordinances issued by Lombardy region and enforced by National D.P.C.M. of 11th March 2020. This trend started to be clearly inverted since the beginning of May when the National D.P.C.M. of 26th April 2020 establishes the beginning of Phase 2 that allowed the reopening of several commercial activities and gradually re-instate the freedom of movement for people.

According to Figures 8 and 9 and coherently with expectations, a decreasing trend for measured noise levels is observable since 11th March 2020 and an increasing trend is advisable since the 4th May for all sensors.

Concerning the comparison between data collected in the correspondent periods of 2019 and 2020 (Figure 12), there is a very good alignment between noise levels related to the periods just before and just after the spread of COVID-19 pandemic in Italy, while the lock down phase is easily recognizable.

In particular, regarding the period from January to March, differences of one dB at most have been found between 2019 and 2020 (Figure 13) while regarding the period May-June, higher differences but of 4 dB at most have been envisaged between 2019 and 2020 (Figure 14), being noise levels measured in 2019 always higher than those in 2020. This last consideration is coherent with result achieved in Figure 11, showing that noise levels measured after the lock down period are lower than the ones measured before the lock down.

Regarding the difference in terms of noise reduction obtained for each sensor (Figure 10), it can be observed that for some sensors (e.g. T0013, T0015) not located in proximity of the main street of the district (Viale Libertà) noise reductions up to 10 dB have been achieved between January and April 2020. This can be due to the fact that traffic on Viale Libertà, as the main source of noise in the vicinity of the avenue, has been reduced but probably not as much as traffic on secondary roads, due to the movement of workers on the main road.

Regarding noise reduction measured by each sensor in the phases of pre lock down, lock down and post lock down, it can be observed from Figure 11 that beside the reduction envisaged from the first to the second phase, in the third phase noise levels increase again but do not reach those observed in the first phase. This may reflect the fact that many people have continued to work from home and that road traffic noise has not yet returned to pre lock down levels.

5 Conclusions

The spread of COVID-19 pandemic, apart from the tragic consequences for many people's life, has resulted also in positive outcomes concerning the environment, with impressive air quality improvements and noise levels reduction.

Such benefits for urban acoustic climate are well evidenced also by the smart noise monitoring system developed in the frame of the LIFE MONZA project and installed in the pilot area of the Libertà district in Monza (Italy). The smart noise monitoring network, made of 10 sensors, has been continuously collecting noise data since June 2017 and was periodically verified.

It can be concluded that noise measurement, also carried out with a smart and low-cost noise monitoring system, can be recognised as a solid environmental indicator of changes higher than 2 dB, as the pandemic event.

Referring to noise reduction obtained during the lock down period in Monza, in the period from January to April 2020 noise levels reductions between 6 dB and 10 dB have been obtained and they are reasonably due to the several measures put in place to slow the spread of the pandemic.

Furthermore, from the comparison between data collected in 2019 and 2020 and referred to the same periods, a very good data alignment can be envisaged for the period just before the lock down (maximum difference for the same sensor equal to 1 dB), while a less good alignment is envisaged for the post lock down period (maximum difference for the same sensor equal to 4 dB). This result, together with the data comparison made between the pre and post lock down period in 2020, demonstrates that noise levels have not yet returned to the ones prior to the lock down period.

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