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Noise Measurement With a Smartphone App as Part of an Environmental Education Activity Conducted in a High School in Treviso, Italy

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Abstract: As part of an environmental education program, some classes of the "Duca degli Abruzzi" High School in Treviso, carried out traffic noise measurements, in collaboration with the Regional Environmental Protection Agency of the Veneto Region (ARPAV). To collect the noise data, students used OpeNoise, a smartphone app developed by the Regional Environmental Protection Agency of the Piemonte Region (ARPA Piemonte). Through the activity, students were introduced to the concepts of acoustics and to the importance of devices' calibration. They were explained how to take into consideration the measurement uncertainty and shown how it is possible to predict the measurements results with the use of an empirical model. Students had also the opportunity to process the noise levels data themselves and present the results.

Key words: acoustic education; mobile devices; sound level measurement application

1. Introduction

The collaboration between ARPAV and the "Duca degli Abruzzi" High School started in 2017 within the framework of the International Noise Awareness Day (INAD) promoted by the Acoustical Society of Italy (AIA) and continued as part of the dual-training system of the Italian school.

The dual-training system (alternating education and practical work-related training) was introduced into the Italian school system in 2015 by Law No. 107/2015, with the aim of consolidating the students' knowledge, strengthening both their theoretical and practical skills, enriching their education, improving their employment prospects or guiding them through their college choice. In the Italian licei (college-track high schools), the education-training program accounts for ca. 90 hours across the school year.

The activity included: an introduction to the concepts of environmental acoustics and to the legislation on noise pollution; an explanation of the usage and functions of the smartphone app OpeNoise, which was developed by ARPA Piemonte; an introduction to devices´ calibration; road-traffic noise measurements on the field; a final presentation of the noise measurements results.

2. Material and Methods

2.1 Introductory Lessons

The first part of the activity consisted of a lecture introducing the key concepts of acoustics and the legislation on environmental noise. Students were introduced to the distinctive physical quantities of sounds and noises (amplitude, wavelength, frequency,

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etc.) and to the use of decibels for the representation of noise levels.

Additionally, in order to explain them the concept of equivalent sound level, the real-time data collected by a sound-level meter (time history, spectrum, linear and weighted sound levels) were projected live on a screen in the classroom. Visualizing the real-time noise level data, combined with running Leq, helped in fact the students to grasp the concept behind this important noise indicator.

Since the students were going to record urban traffic noise, they were also introduced to the Italian legislation on noise pollution.

Finally, the lectured covered also the possible negative effects of noise on health, a topic which was very relevant for the students given the widespread use of earphones and headphones for listening to music.

2.2 The OpeNoise App

OpeNoise is an mobile application developed by ARPA Piemonte [1, 2] available for both Android and iOS devices, which allows the user to simulate the use of a sound-level meter, measuring the minimum and maximum sound level, the L_{Aeq} (A-weighted, equivalent, continuous, sound level) with a user-defined sampling-time and the running Leq.

With OpeNoise it is also possible to perform frequency analysis, both in third octave and FFT. According to the app designers, a good linearity of at least 45-80 dB (A) can be achieved on all smartphones, as well as a linear frequency response between 200 Hz and 5 kHz.

Students installed OpeNoise on their smartphones and, with the help of slides, were introduced to its various functions, including the possibility of storing data logs in a text file format, which can be then imported into a spreadsheet for further processing and graphic representations.

2.3 Device Calibration

A prerequisite for the correct use of OpeNoise is preventive calibration, which allows the user to set the smartphone´s gain correctly. This operation can be done by matching the smartphone with a precision instrument, in our case study a class-1 sound-level meter, subject to biennial calibration in laboratories approved by the Italian calibration system.

During the first year of collaboration with Liceo “Duca degli Abruzzi”, as well as in other similar projects developed with other high schools in Treviso, the calibration was carried out by placing the smartphone next to the microphone of an Arpav sound-level meter, near a source emitting stationary noise.

The first calibration attempts in the proximity of sound sources (as for example a speaker, a constant-speed combustion engine or a small waterfall) were however unsatisfactory, mostly because of environmental noise´s interference. It was therefore decided to build a mini reverberation room, inside of which to pair the sound-level meter with the smartphone.

A portable radio without an antenna was used as stationary noise source, as its typical static noise resembles white noise. The reverberation chamber used for the experiment (Fig. 1) is a box measuring 400 × 350 × 210 mm^3, with a double partition (an external 12 mm wooden wall and an internal 0.6 mm zinc-coated folded metal sheet), designed to be easy to move and to use and offering sufficient acoustic insulation from the outside (empirical measurements have indicated a reduction of about 25-30 dB).

The box was equipped with a “control window” (Fig. 2) to facilitate the comparison with the reference instrument (the class-1 sound-level meter). The microphone of the sound-level meter was introduced into the chamber through a hole, while an adapter for ½" microphones was placed on the inside. A press for cables was installed on the outside to guarantee mechanical seal, as well as sound insulation.

Once the reverberation chamber was ready, a uniform sound field area was identified inside it, where the microphone of the smartphone undergoing calibration was then placed.

The correct calibration of the smartphones was essential to the experiment, as it has been recorded that, with a faulty or missing calibration, the difference between the "true" sound level and that actually registered by the phone could reach 15-20 dB.

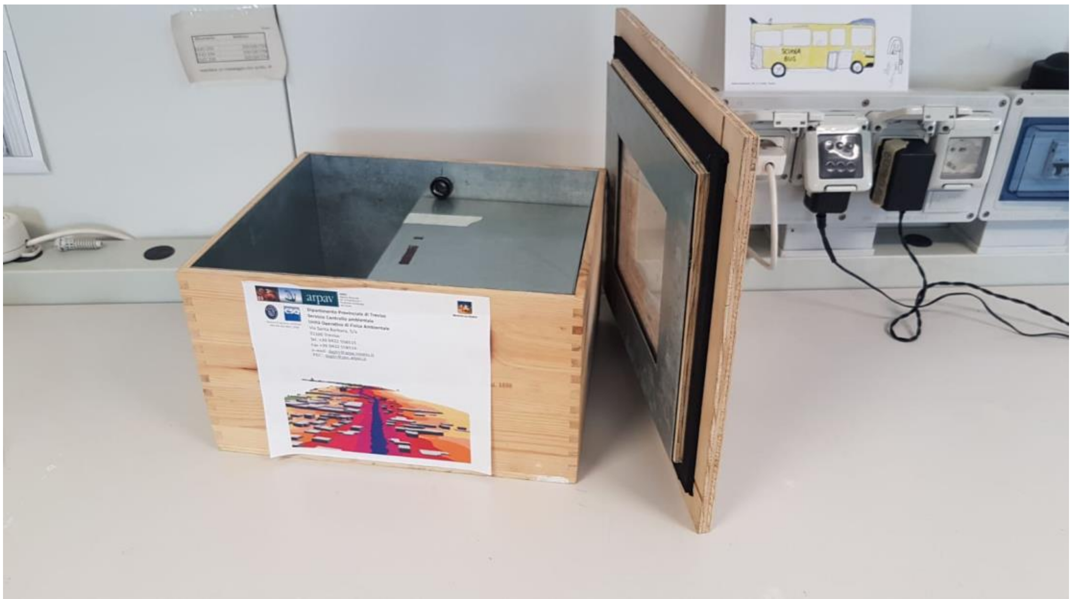

Fig. 1 Reverberation chamber for smartphones calibration; the photo shows the reverberation chamber, with the walls covered by the metal sheet; the lid with a closure seal of expanded rubber with a density of 130 kg/m^3; the control window in Plexiglas.

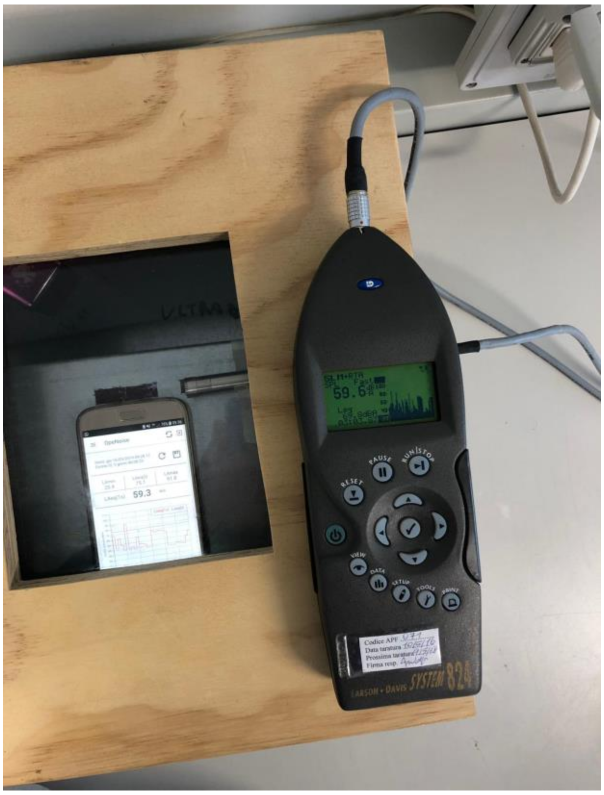

Fig. 2 Calibration of a smartphone paired to a sound-level meter: the sound level indicated by the smartphone and that displayed by the sound-level meter are compared through the control window.

3. Results and Discussion

Fig. 3 shows a sample of the results of smartphones calibration carried out by a group of students. Although the average level is 79.3 dB (A), rather close to the reference level of to 80 dB (A), in terms of absolute value, the deviations of the different smartphones are between 3 and 8 dB.

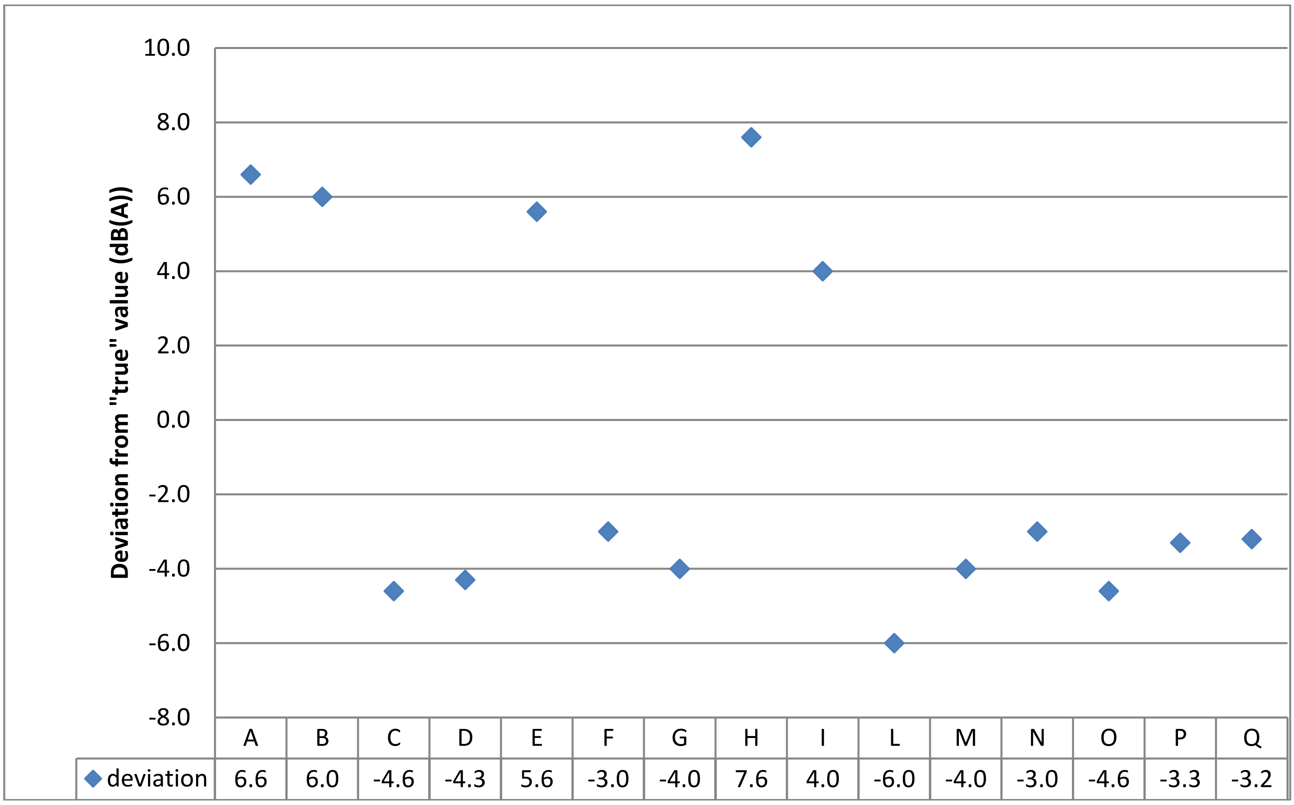

Fig. 3 Smartphone calibration results: example of smartphone calibration results by a group of students, before adjusting the gain.

Smartphones with a positive deviation from the reference value, are either by Samsung or have an Android operating system, while the smartphones with a negative deviation have Apple iOS as operating system, suggesting that smartphones receive some sort of sound calibration already in the production phase.
The school which participated to the program stands next to a highly-trafficked, one-way road inside the medieval walls of Treviso. Students, divided in group of 4-5 peers each, carried out road traffic noise measurements, while at the same time keeping count of the vehicles driving by.

Before the morning chosen for the measurements, students were showed with a short video tutorial, guiding them through the OpeNoise settings.

On the same morning, ARPAV carried out road traffic noise measurements on the same street, using an ARPAV sound-level meter, in order to gather data which could then be compared to those collected by the students.

The experiment showed that, if the smartphone calibration is done correctly, the road traffic noise results obtained with smartphones and those obtained with a class-1 sound-level meter are comparable, with discrepancies within a 1.5-2 dB range. The students also estimated sound levels on the basis of traffic flow data, using an empirical formula developed by the Pescara Provincial Department of ARTA, the Regional Environmental Protection Agency of the Abruzzo Region [3].

Fig. 4 shows the results of the Leq measurements carried out by small groups of students in November 2018, compared with the data measured by the reference sound-level meter: the standard deviation is around 1.3 dB (A). When in 2017 the calibration was carried out with less accuracy, by placing the phones next to the sound-level meter and then placing them both in front of a loudspeaker in a classroom, the average deviation in the traffic noise levels was around 3.5 dB (A), with deviations from the "correct" value sometimes even around 5 dB (Fig. 5).

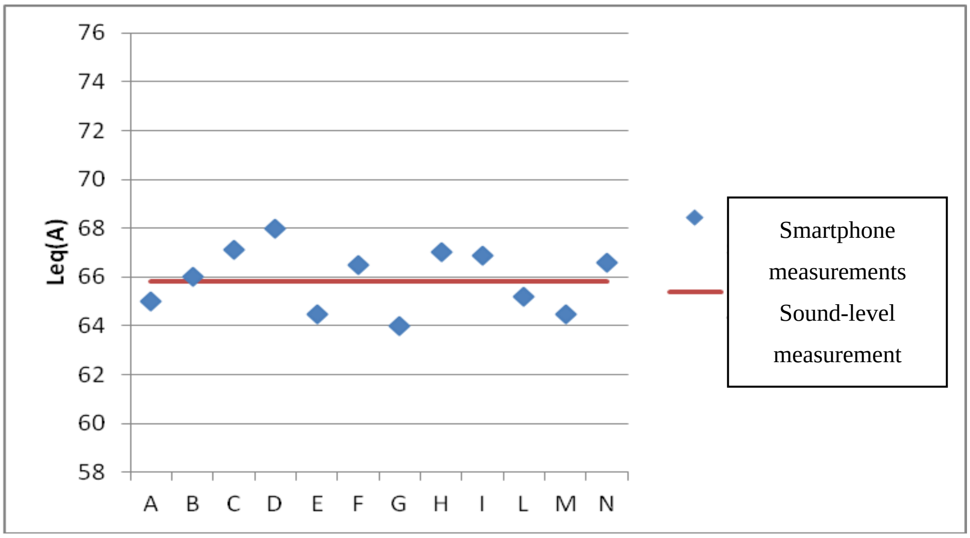

Fig. 4 Results of traffic noise measurements carried out in 2018 after smartphones were calibrated using the ad-hoc device; the capital letters indicate the different students groups; the sound level measured with a sound-level meter, with a measurement time of 20 minutes, was 65.8±1.0[1] dB (A); the average sound levels detected by the smartphones was 65.9 dB (A), with a standard deviation of 1.3 dB (A).

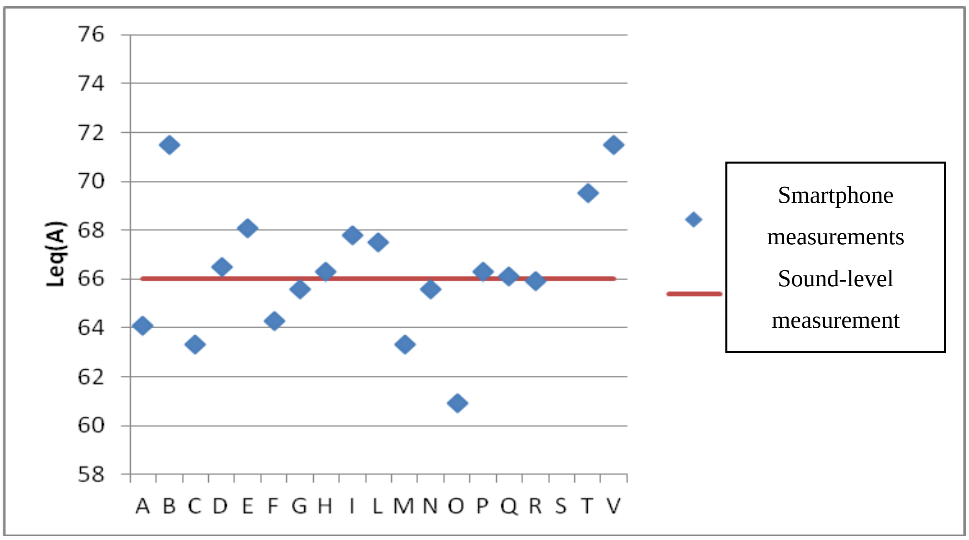

Fig. 5 Traffic noise data collected in 2017 with smartphones calibrated on open field using a loudspeaker; the letters indicate the different groups of students; the noise level obtained with a sound-level meter.

[1] Expanded uncertainty with coverage factor k = 2, at a confidence level of ca. 95%

4. Conclusion

The tests showed that, if smartphones are properly calibrated, they can obtain results comparable to those collected with a class-1 sound-level meter, with a difference in the traffic noise levels within 1.5-2 dB.

Students found the activities interesting and discovered a new and unexpected way to use their smartphones. Although the study program of Liceo's third grade does not cover some key acoustic concepts, as for example wave phenomena and logarithms properties, by using their own phones to measure noise, students were still able to grasp some other important physics concepts, as sound level, equivalent sound level and frequency analysis. However, for this reason, it has been decided that in the future similar programs will involve fourth graders, who will have already studied wave phenomena with their physics teachers.

Students were also able to acquire "citizenship skills", as they approached the legislation on environmental noise pollution and the related area of responsibility of public institutions as such as Municipalities and ARPAV.

Finally, the students realized the importance of the calibration of measuring instruments and, by comparing their results with those obtained by their peers and with those provided by a precision instrument, they were able to directly ascertain the degree of uncertainty which often affects measurements data. In particular, students understood the importance of expressing the results of a measurement or of an estimate with the correct number of significant figures.

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