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# Industrial plant noise mitigation starting from the plant first runs.

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**ABSTRACT**

*The article summarizes a noise impact mitigation study that was carried out in the Liguria region in Northern Italy, between July 2020 and March 2022 on a large industrial plant that produces zinc oxide.*
*The authors were summoned at the plant first run tests, so this study started without a participation in the industry planning and design phases. We followed the main machine installations and perfected the mitigation project accordingly: priorities were updated after each assessment and new modelization.*
*This approach was carried out with different SPL measurement campaigns and the use of sound-intensimetry and a beam-forming SEVENBEL antenna. A SoundPLAN 3d model was updated step by step, defining a designing ad hoc noise control strategies and solutions, in order to respect the Italian administrative noise regulations.*
*The mitigation works were directed by one of the authors and included different approaches: such as some large cylindrical silencers on the smoke stacks, sound barriers and insulating coatings, as well as fan velocity optimization.*

## 1. INCIPIT

An industrial oxidation plant was starting the first plant tests in Northern Italy during the first COVID-19 pandemic period of 2020; the area had an industrial destination of use but had been abandoned for years before the plant settlement. Unfortunately, little acoustical planning was done during the design phases of the new plant.
Complaints from the nearby houses started immediately: the authors were summoned to assess the respect of the township noise limits (DPCM 14/11/1997 [1]) and study noise mitigation strategies as the numerous parts of the industrial plant were started. COVID-19 period restrictions delayed the machine installations, the authors' visits to the site and also made it difficult finding materials for the actual noise containment solutions.

Figure 1 - Main Receiver R1 in red – P1/2 measurement point in blue

The main noise source was related to the numerous fans the industry uses inside and also outside the main building. All of these fan ducts were conveyed to two massive 40 m steel smokestacks that were positioned, approximately 110 m from the nearest inhabited buildings on the South-West side: the noise problem was geometrically contained in a 200 m by 200 m area (yellow square in fig.1) with one worst exposed receiver (R1 – red circle). An equivalent control point was found in a free access field close to the receiver (P1/2 – blue dot).
The first target was to lower noise annoyance to the neighborhood, then to lower the internal noise in the main building. The main difficulty was related to the fact that the industry was starting new plant parts and increasing its productivity as we studied, so, for each noise insulation assessment, we had to fight against an increase in number of fans and their setup.

## 2. ADMINISTRATIVE NOISE REGULATION IN ITALY

The administrative legislation on environmental noise in Italy is mainly based on two Acts: Act 447/95 [2] "Framework act on noise pollution" and the Prime Ministerial Decree 14/11/97 "Determination of limit values of sound sources" [1]. The former is the general Act on all noise management issues: it introduces definitions and illustrates the responsibilities of the State, Regions, Provinces and Municipalities on noise regulation in Italy. Starting from this, many implementing decrees have been issued.
Very important is the Prime Ministerial Decree of 14/11/97, in which the noise emissions in the outside environment for activities are regulated. In particular, the limits are defined as:
- the absolute immission and emission noise levels. These are the noise LAeq levels that must not be exceeded by the environmental level average and the noise energy average on the overall

daytime period (6-22) and the overall nighttime period (22-6). These are generally applied at the receivers, 1 meter outside from the facade and depend on the acoustic class they belong to.

- Differential noise levels are the maximum differences between residual noise LAeq level (with activity off) and ambient noise LAeq level (with activity on) that an activity can create:
5 dB in the day period (6-22) and 3 dB in the night period (22-6)
They are applied at the receivers, inside, 1 m from the open and closed windows.
The two limits must always be jointly respected.

The receiver area was set by the Municipality zoning plan in IV class with absolute immission limits 65 dBA day-time and 55 dBA night-time; absolute emission limits 60 dBA day-time and 50 dBA night-time. These were strict limits for a large industrial area.

Residual night-time noise level was measured in accordance with ARPA (the Administrative Regional Agency for Environment Protection) in December 2020, this LAeq = 46.5 dBA value became the baseline for further verification.

## 3. NOISE ASSESSMENTS AND SOUND INSULATION STEPS

### 3.1 First measurement campaign - July 2020

In July 2020 we carried out a short period SPL measurement campaign to start assessing the environmental noise situation ourselves. The major limit excess was confirmed in a specific area South of the plant: the noise assessment at receiver R1 was a 13 dB night differential level against the 3 dB limit.
Numerous leaks in the main building were identified: in the area where the main ducts exit the building walls, we measured 92 dBA with a pure tone at 315 Hz. Measures were carried out simultaneously with two SPL meters with microphones at 4 meters height. All of this led to a first SoundPLAN 3d simple model.

The first mitigation step was to design sound insulating booths on the main and noisiest fan motors inside the main building (this was important for worker protection – noise limits set by D.Lgs 81/08 [3]). We proposed also sound insulation of the leaks around the main tubes exiting the main building and a large sound insulating barrier on the lower part of the smokestacks.
Fan velocity regulation was not considered at this stage because the client wanted to continue testing the machines and regulate full capacity to correct it for real.

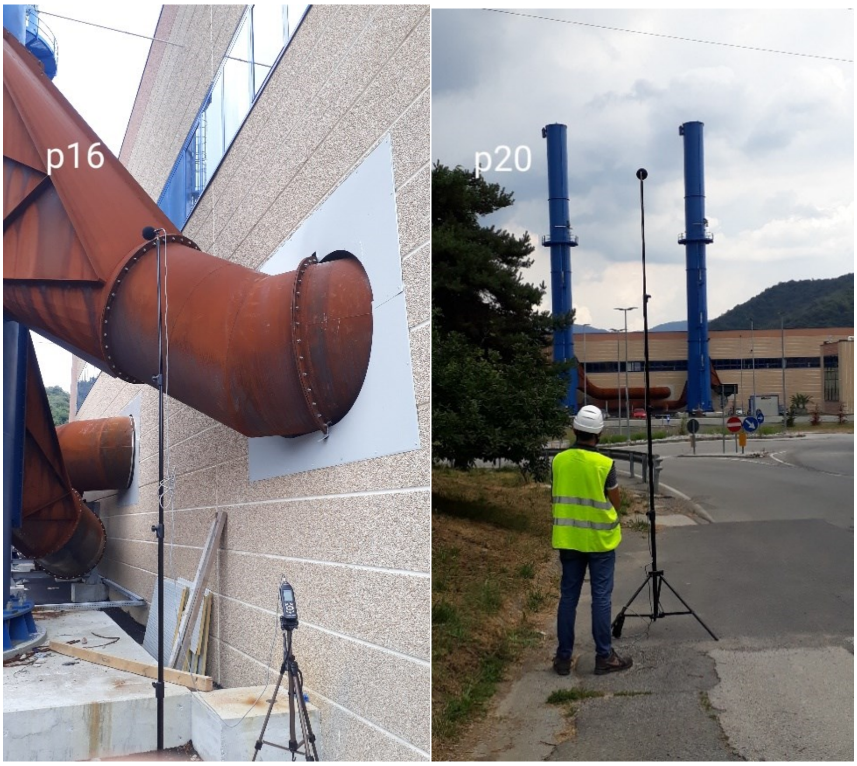



Figure 2 - Leaks in the façade 2 out of 20 short period measurement points

### 3.2 Second measurement campaign – September 2020

New fans had been set up and started, even outside in the main corridor between the two Southern buildings (figure 3 shows the main receiver R1 in a circle), we used the SPL Meters and a sound intensity probe to study noise control solution for the fan motor noise emission, inside the plant, and the emission from the duct and their interconnections (figure 4).

Figure 3 – new fans looking at the main receiver R1

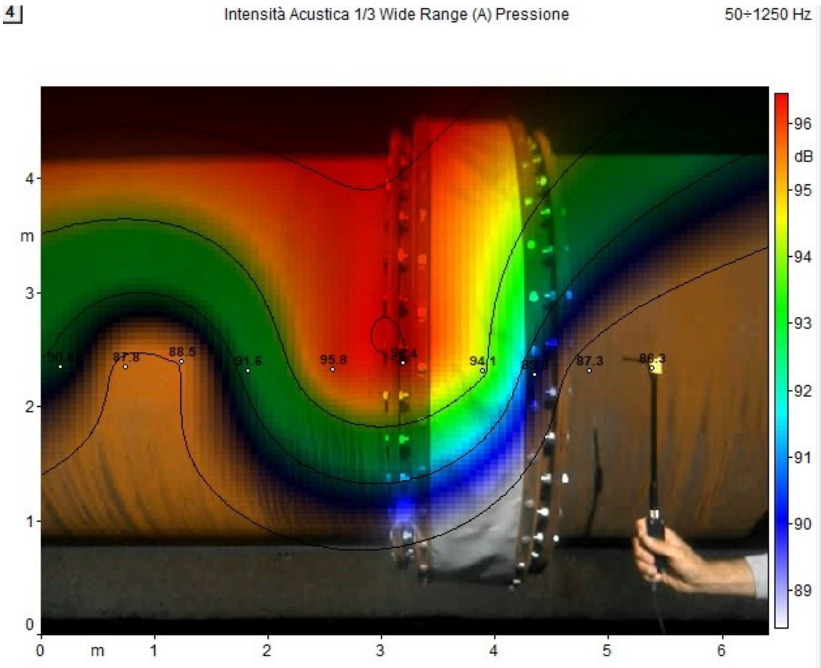


Figure 4 – Sound Map with Sound probe and Giotto software

A better design for sound insulating was better devised, especially to cover the emission on its side. Some sound insulating booths were devised for the noisiest fan motors inside and outside the building, the duct connections and the points where the ducts actually cross the building façade walls were treated with specific multi-layer ‘SIL-layer’ mats.

### 3.3 Third measurement campaign – January 2021

The barrier was built, the most critical fans were insulated and the acoustic bridges where the ducts cross the main façade were insulated

Figure 5 – Sound barrier and fan enclosing – January 2021

At this stage four main sound sources were defined: S1 the two smokestack tops, S2 the remaining connections between the external ducts and S3 the main corridor between buildings that conveyed noise from the Northern areas.

Figure 6 - S1a and S1b sources on the left and S2 on the right

At this point a SevenBel beam forming acoustic camera was quite useful in assessing the importance of sources S1 smokestack tops versus the quantity of noise escaping from the tunnel between the two southern buildings.
Here the choice of camera observation points is vital to assess information, this choice should be directed from actual hearing experience on site.

Changing observation point gives different information: framing both the chimneys and the barrier some noise was also seen in the lower area (figure 8). This phenomenon can be explained for several reasons:

- you can observe the noise coming directly from the mouth of the tunnel;
- this noise that is reflected on the barrier is also significant;
- a portion of the noise survives behind the barrier and reflects against the chimney and the wall;
- a surviving structural connection with the pipes was noticed which caused the barrier to vibrate and this fact was to be corrected with small interventions;
- the surviving noise going through the barrier panel is a minor problem.

At this point two large cylindrical silencers were proposed for the smokestacks' tops and we advised to close the tunnel entrance, this was not actually needed from a logistical point of view and so we proposed a masonry wall.

Time interval: 0.000 s - 1.440 s | Video: Off
Bandwidth: 426.6 Hz - 7043.4 Hz

ACOUSTIC IMAGE

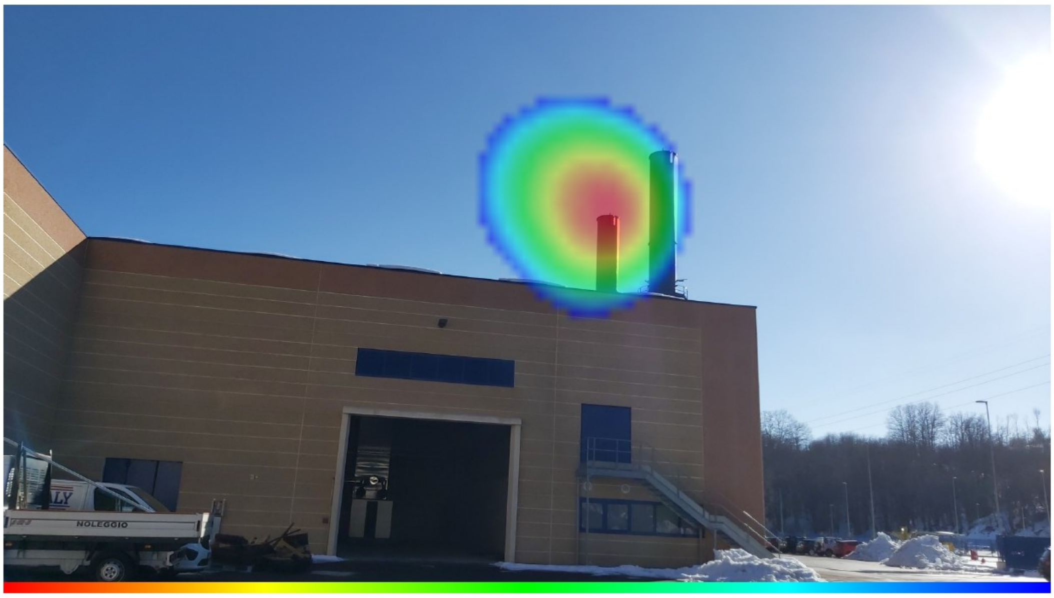
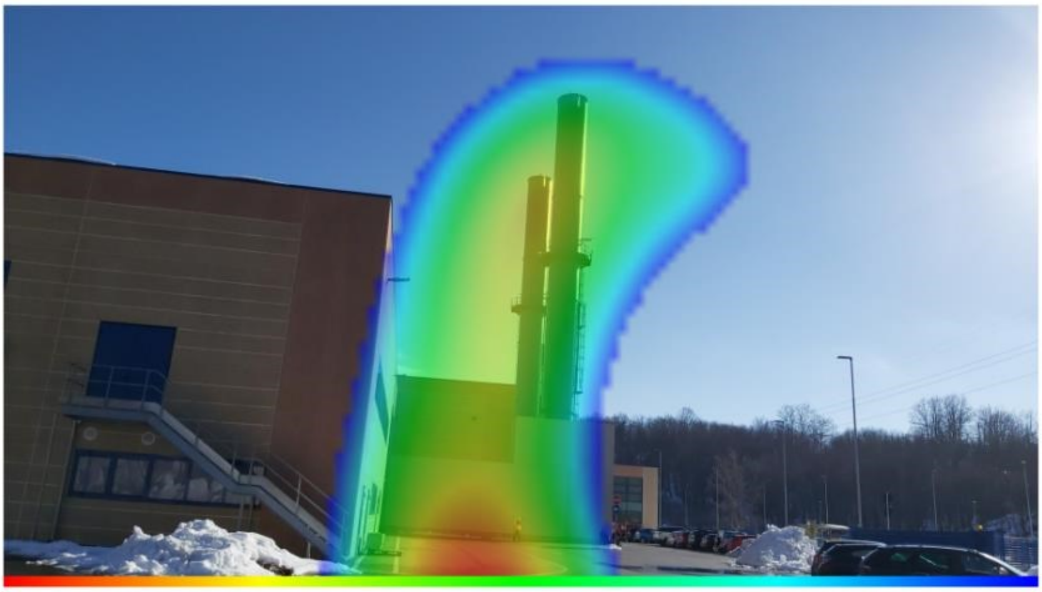


Figure 7 - Analysis point X2 sonocamera

Bandwidth: 416.2 Hz - 6887.3 Hz

ACOUSTIC IMAGE

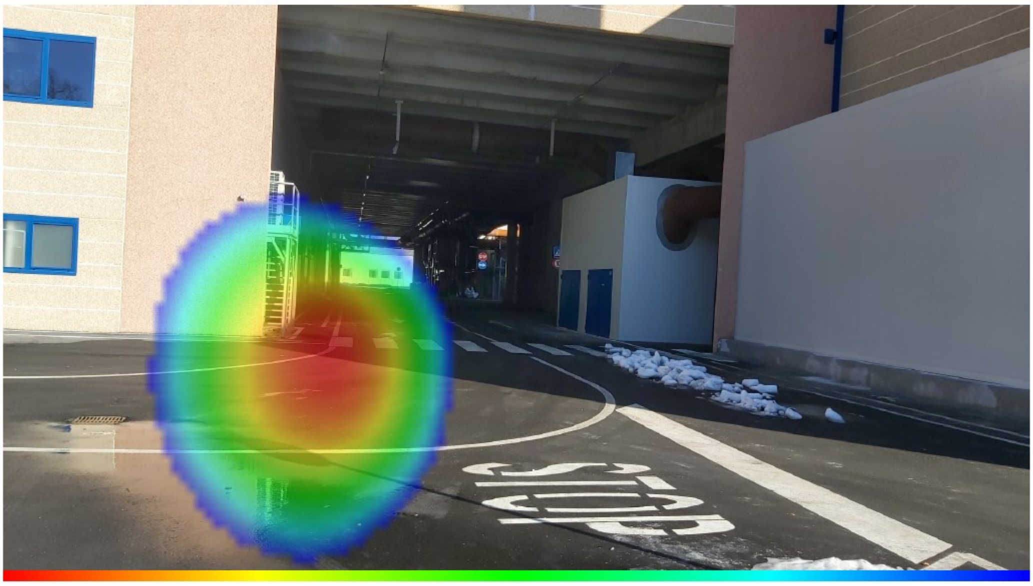


Max SPL Image: 45.63 dBA | Total SPL Ref Mic: 57.62 dBA
Dynamic range: 0.8 dB | Bandlimited SPL Ref Mic: 55.04 dBA

Figure 8 - Analysis point X1 sonocamera

Bandwidth: 135.2 Hz - 3984.7 Hz

ACOUSTIC IMAGE



Max SPL Image: 52.97 dBA
Dynamic range: 0.4 dB

Total SPL Ref Mic: 64.11 dBA
Bandlimited SPL Ref Mic: 63.65 dBA

Figure 9 - Analysis point X3 sonocamera

### 3.4 Fourth campaign - April 2021 - longer measurements at the most exposed receiver

At this point we had access to the actual receiver R1 house, so we set up a one-week measurement system on the balcony. This was decided to assess the influence of temperature, wind velocity and smokestack use on the sound level. Since the balcony oversees two roads the LA90 value on one-hour segments was preferred to assess the situation.

Figure 10 – Week long measure at the R1 receiver balcony

The orange line in the two graphs is the hourly LA90 sound level value, it oscillates in the 54 dBA to 57 dBA range (the absolute immission limit for the night is 55 dBA and was almost respected). L90 level best assesses the noise because it excludes traffic influence and we are looking at a stable sound source.
We had confirmation that the P1/2 control point was a solid reference.

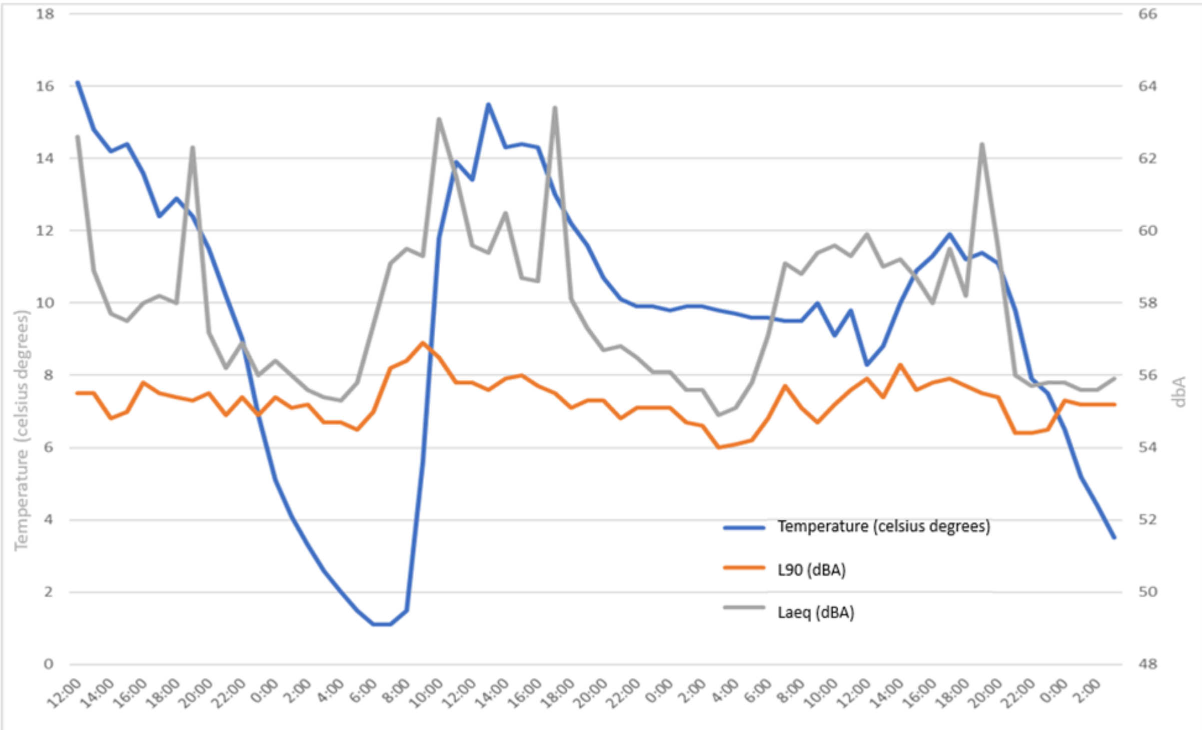



Figure 11 – 3-day focus studying temperature variation

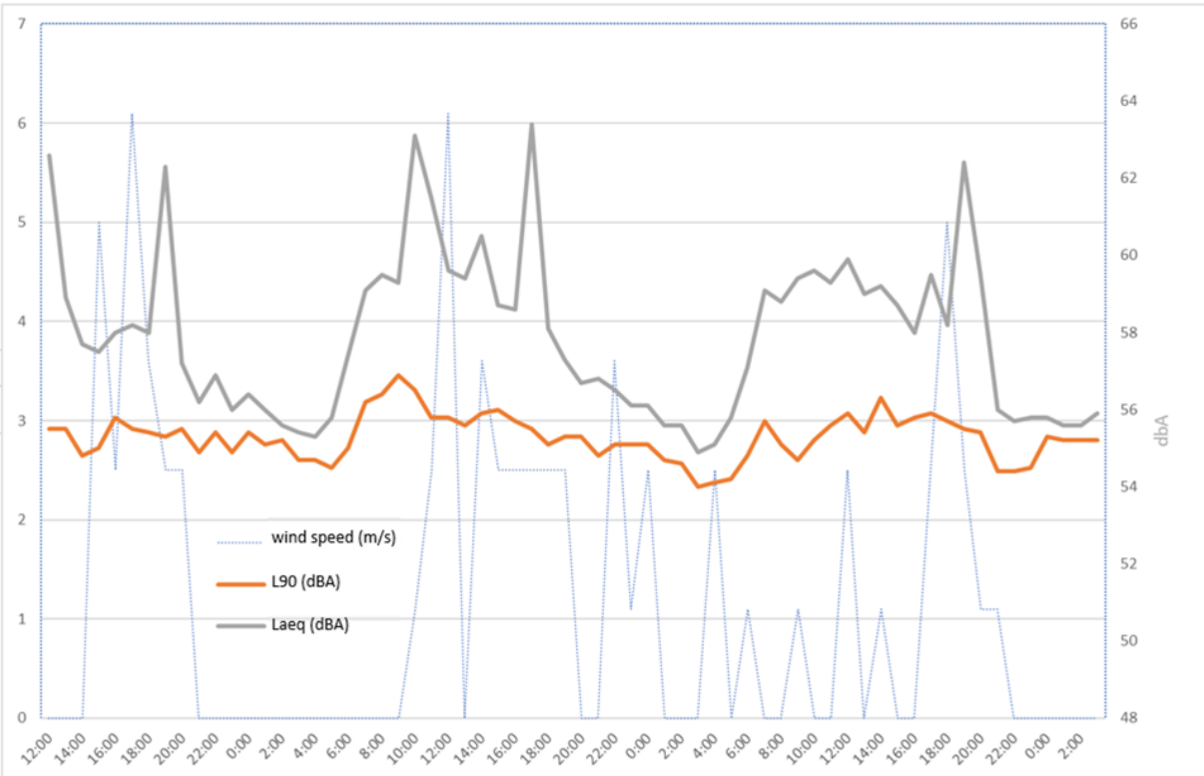



Figure 12 – 3-day focus studying wind velocity variation

There are no evident correlations between the trend of sound levels and those of temperature and wind intensity in the recorded range. It is believed that this fact is due to the proximity of the plant to the receptor. We realized R1 at this stage was receiving significant noise also from a third-party nearby paper-mill factory.

We studied also the sound level correlated to the smokestack velocities: there were a 1 dB drop when both chimneys were at minimum and an increase in emissions from both chimneys at maximum of 1 dB.
The spectrum comparison between hourly measurements confirmed there was a maximum at 400 Hz and 125 Hz, energy at 800 Hz was changing more significantly. When flux velocity was controlled the maximum at 400 Hz lost energy and this confirmed that changing the overall flow rates in the night was an important strategy.

At this stage we decided to design a circular silencer for each smokestack and start studying for optimizing the night fan velocity regime.

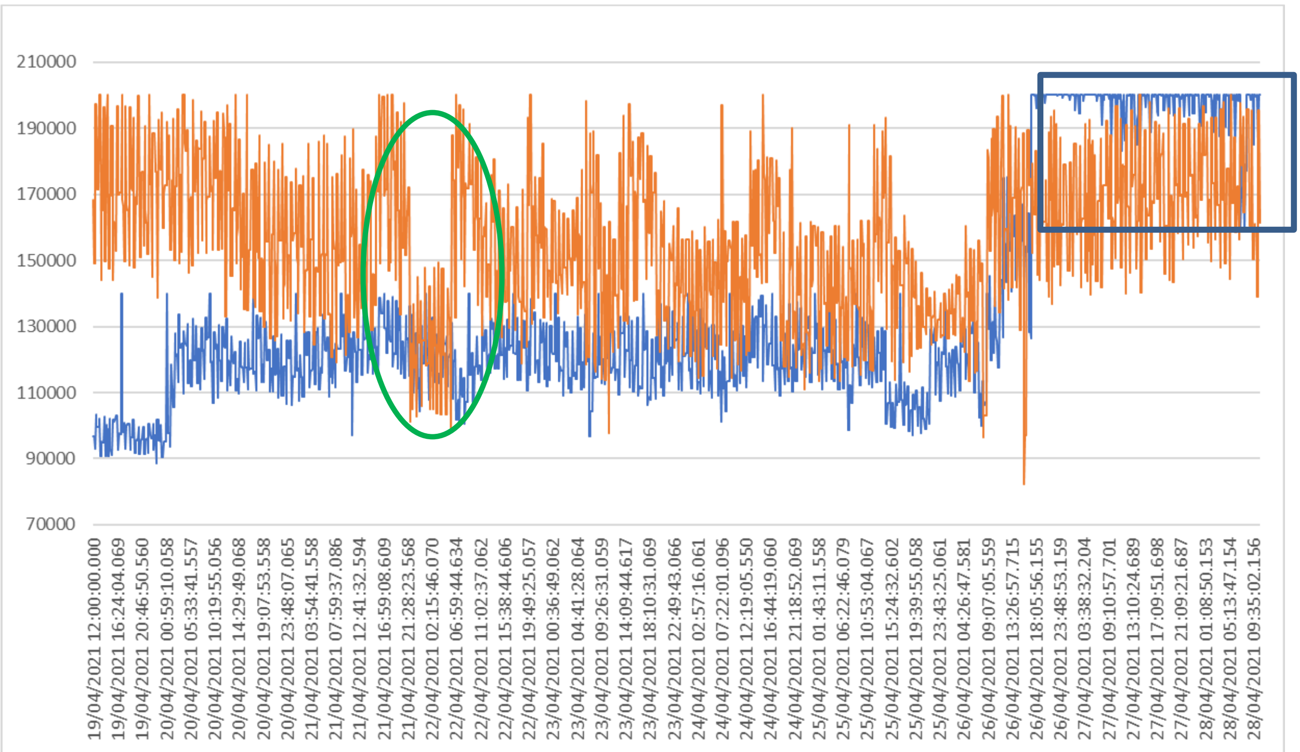



Figure 13 - Display of chimney emissions as measured by our client

A short measurement campaign in the industry property was set-up to test 2 different plant production night regimes (setup B versus setup C)
Setup C was 5 dB less than setup B and was the right choice to respect the absolute emission level.


Figure 14 - Night minimum values spectra at the outside P1

As we can see energy drops at all frequencies between 31,5 and 5000 Hz

| Set-up | Measurement point | LAeq | L90 |
|---|---|---|---|
| B - Night | P1 | 58,4 | 58 |
| C – Night | P1 | 51,8 | 51,4 |

The L90 level drop of about 6,5 dB is important to comply with rule values.

### 3.5 Fifth campaign - October 2021 – smokestack's silencer testing and plant regime optimization

The top chimney summit quains were substituted by two t cylindrical silencers with a reduced ogive Silencer design that was defined by using Beranek's manual [4]

To evaluate the actual silencer noise reduction, we followed two choices a 'cold' test with an artificial source (ISO 11820 [5]) when the silencer was lying on the ground on the construction site and an evaluation of the 'hot' data provided to us by the measurements with the silencers installed on site for control point P1/2

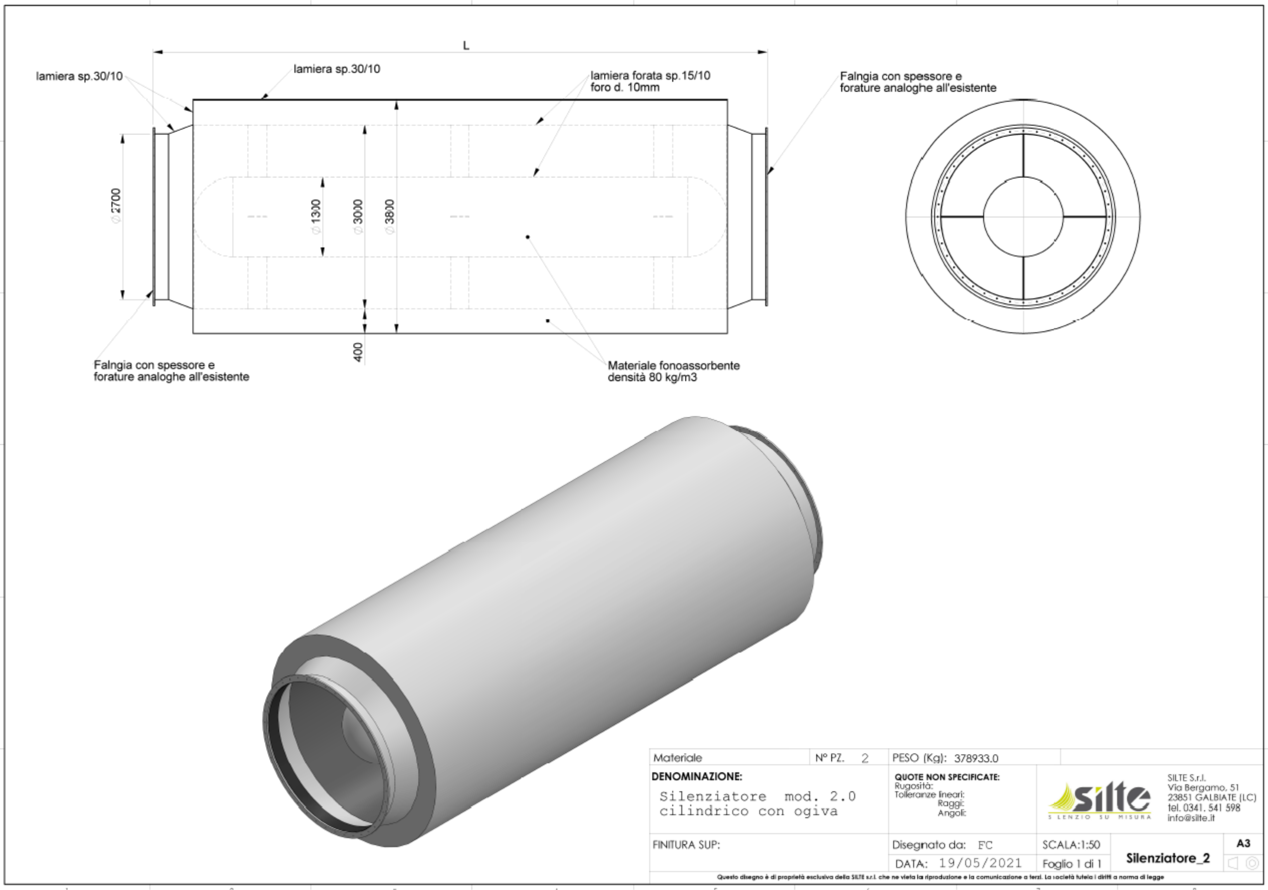



Figure 15 - Preliminary drawing of the silencer.

The sound insertion loss results (figure 16) are different because in the 'hot' case the chimneys are measured with the air-flux present, plus there are many directionality effects as well as the presence of the various plant sources which were previously secondary and which become predominant on the control point P1/2 and which therefore underestimate the actual insulation in place.

So, in the artificial tests, when laying on the ground we can check the theoretical result but it is not what you observe live in P1/2, due to the presence of other noise sources and the effect of the air-flux.

These data tell us that the attenuation obtained 'hot' (dashed blue) at the remote P1/2 control point, near R1, is lower than the attenuation given 'cold' measurement by directly testing the silencer.

This was expected because, at this stage of the distance, the effect of the silencer is partly nullified by a third-party company sound sources which were previously secondary, this is evident in the gap in attenuation from 200 to 1250 Hz.
The evident gap between the two curves in the attenuation data at 315 Hz indicates that there are pipes and/or windows from which the noise existing as we know coming from the fans still escapes

The final result gave an average attenuation over the three octaves of interest of 12.3 dB when 14+/-3 dB of average attenuation had been expected during the design phase.

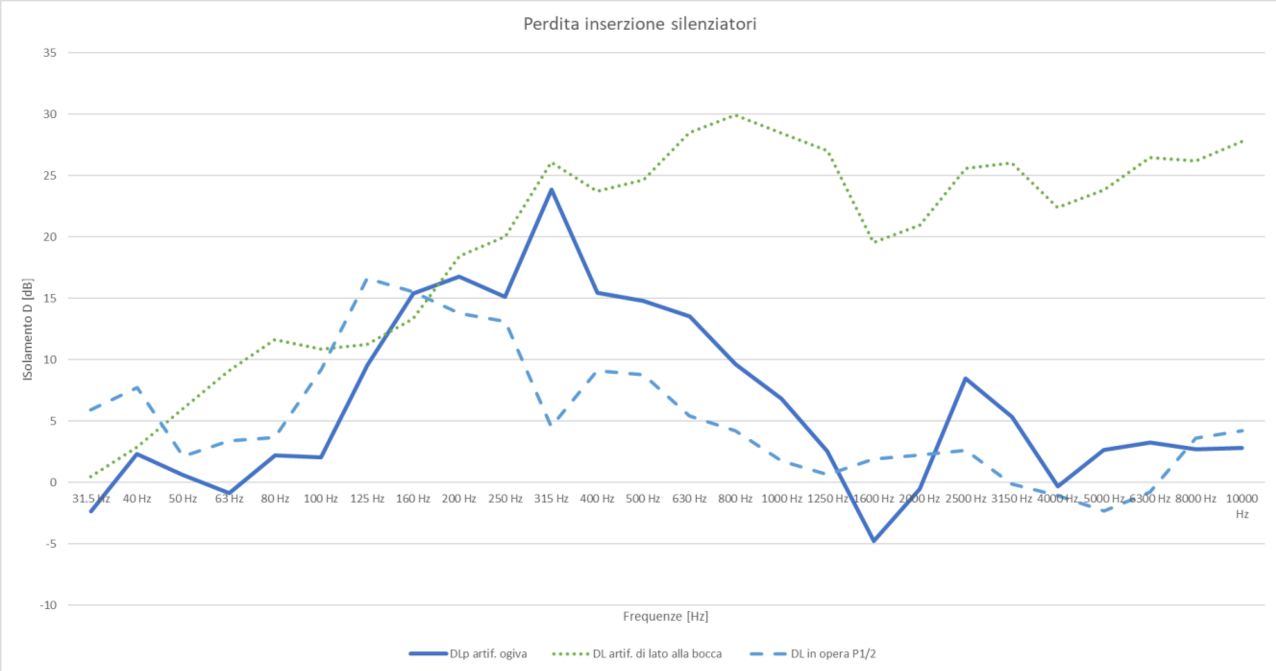



Figure 16 – IL(f) - solid blue artificial source – dashed blue actual reduction remote P1/2

Figure 17 – Cold test before silencer mounting

The following graph shows the frequency values in the P1/2 control point near the R1 receiver: the Dashed line shows two residual measurements (December and august), both show more energy at 1000 Hz octave band; the dark solid line is the ante-operam value; the orange and blue solid lines are the post-operam values for two minor differences in fan velocity setup (after the silencers installation).

At this factory set-up the differential level in P1/2 was 0.5 dB. We started at 13 dB against the 3 dB night limit. Both the absolute night limits were respected.

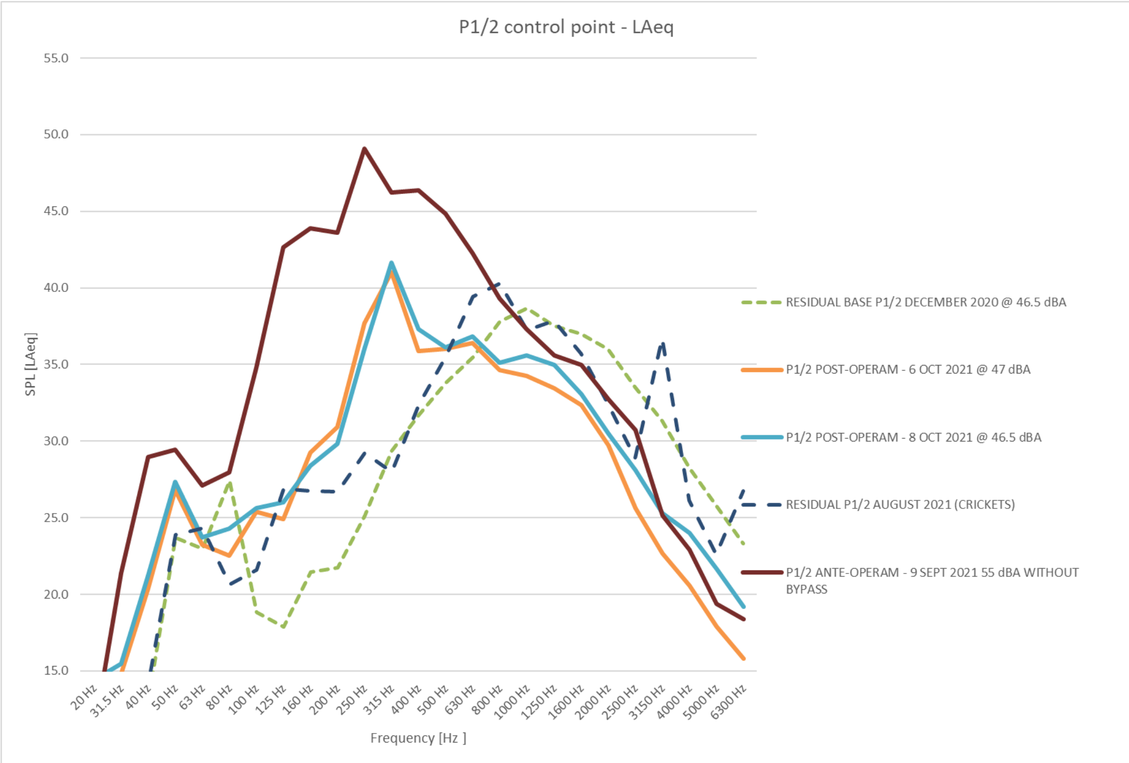



Figure 18 - Frequency analysis in P1/2 control point after silencer mounting

### 3.5 Sixth campaign – March 2022 – internal noise and acoustic camera assessments for further improvements

The last part was devoted to studying the internal noise reduction in the main building (the one closest to the smokestacks).

An extensive SPL measurement campaign with the help of a SevenBel acoustic camera was carried out: this led to a Ramsete 3D simulation and the decision to work on the tube curves. Motor fan enclosing was proved successful; the experiments with a partial coating with the multi-layer 'SIL-layer' on the tubes was proved successful (figure 19) and we proposed to continue its use.

On the outside the client was asking for ways to protect a potential regime increase in the night period: a final sound insulation proposal of closing the top of the main noise barrier and working on the building roof was given, this was useful to lower the remaining excess energy.

Sonocamera from the P1/2 point (figure 20) was proving an optimal functionality of the silencers with main sound energy coming from the lower part, we assessed a reflection from the wall behind the insulating barrier. Accessing the roof top, we found also major leaks from tube junctions and from the building skylights.

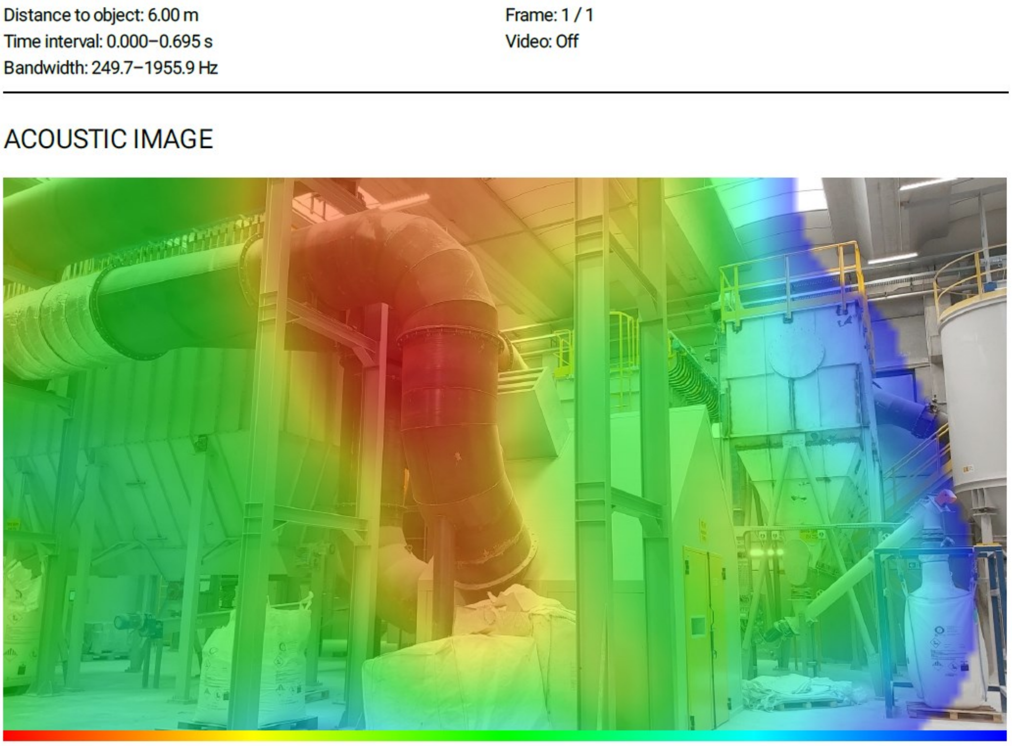



Figure 19 – Sonocamera control inside the main building

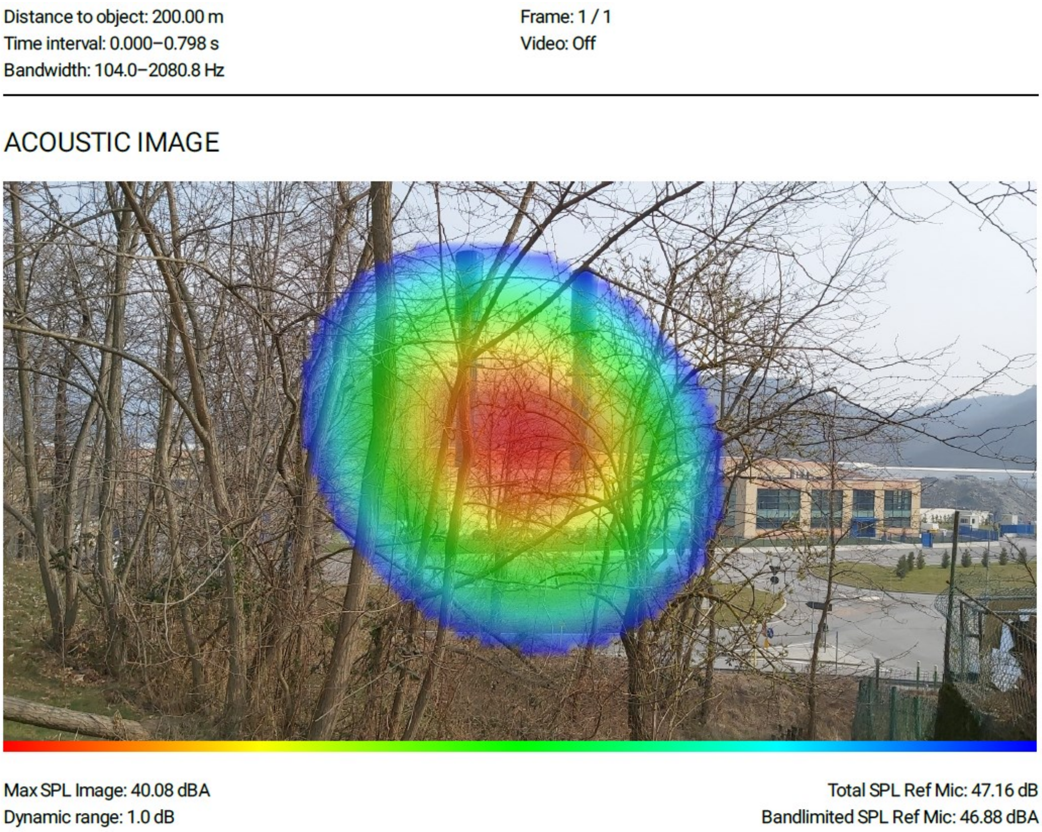



Figure 20 – Sonocamera control from P1/2 point next to the main receiver – march 2022

## 4. CONCLUSIONS

The article summarizes a noise impact mitigation study that was carried out in Northern Italy between July 2020 and March 2022 on a large industrial plant for the production of zinc oxide.

The authors followed the main machine installations and perfected the mitigation project as the factory parts were assembled and started: priorities were updated after each assessment and new 3D modelization.

A SoundPLAN 3D model was updated step by step, defining a designing ad hoc noise control strategies and solutions while dominant noise sources were attenuated and new ones were started and assessed.

Night-time factory regime was kept last and gave the final strong noise reduction.
We obtained total respect of the Italian administrative noise regulations: in particular the situation started in July 2020 with a 13 dB night-time differential level and arrived at 0.5 dB in October 2021 (the night limit is 3 dB over the residual noise LAeq).

Further investigations were studied in 2022 to lower internal noise levels and propose additional external insulation to allow possible higher nocturnal regimes.

## REFERENCES

[1] DPCM 14/11/1997 – Valori limite delle sorgenti sonore
[2] Legge 26 ottobre 1995, n. 447 – Legge quadro sull'inquinamento acustico
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[4] Ver, Beranek – Noise and Vibration Control Engineering – Wiley – second edition
[5] ISO 11820 – Acoustics - Measurements on silencers in situ