Acústica 2008
20 - 22 de Outubro , Coimbra, Portugal
Universidade de Coimbra

NOISE MAPPING OF INDUSTRIAL SOURCES

Luís Conde Santos[1], Christine Matias[1], Frederico Vieira[1] , Fátima Valado[2]

[1] dBLab - Laboratório de Acústica e Vibrações, Lda.,
luis.conde@absorsor.pt ; christine.matias@absorsor.pt ; frederico.vieira@absorsor.pt
[2] dBLabEspaña – Laboratório de Acústica y Vibración, SL
fatima.valado@absorsor.pt
www.absorsor.pt

Abstract

Noise is often one of the environmental variables where it seems more difficult to guarantee full compliance with legal limits in complex industrial situations and/or in other multi-source environments. This paper describes the application of noise mapping techniques to industrial sources, such as factories, power plants, wind farms, showing the potential of its use, both at the design stage as well as for noise reduction plans of existing installations. Starting from the collection of noise sources data, reflecting and diffracting objects, cartography of the area around the site and identification of sensitive receivers, an acoustic model can be built and run according to ISO 9613 standard. This then allows one to produce noise source ranking, according to the individual contributions to the total noise, as well as comparing different noise control scenarios, thus enabling one to optimize the investment in noise control measures. Practical examples in Portugal and Spain are presented and discussed.

Keywords: industrial noise, noise map, action plan, noise control, ISO9613.

Resumo

O ruído é frequentemente uma das componentes ambientais em que se torna mais difícil garantir o cumprimento de limites legais, em situações industriais complexas e/ou em que existem múltiplas fontes de ruído. Esta comunicação descreve a aplicação de técnicas de mapeamento de ruído a instalações de tipo industrial como fábricas, centrais de produção de energia, parques eólicos, ilustrando as suas potencialidades quer em fase de projecto, quer para a concretização de planos de redução de ruído em instalações existentes. Partindo do levantamento de dados das fontes sonoras e objectos reflectores e difractores, bem como dos dados altimétricos do local e dos receptores sensíveis existentes, é elaborado um modelo acústico, de acordo com a norma ISO 9613, que permite hierarquizar as fontes de ruído segundo a sua contribuição para o ruído global, bem como analisar cenários de intervenção correctiva e optimizar o investimento na redução do ruído. São apresentados e discutidos exemplos em Portugal e Espanha.

Palavras-chave: ruído industrial, mapa de ruído, plano de acção, controle de ruído, ISO9613.

1 Introduction

Noise evaluations around industrial premises have been for a long time carried out by means of short term noise measurements, on a limited number of receivers, and by performing some simplified qualitative analysis, eventually with some simple calculations. However, experience has demonstrated that often, and above all in installations of large dimension and complexity, this approach does not enable one to get feasible results neither a clear vision of the real noise impact. Moreover, it does not, in general, produce enough information for decision making with respect to what noise control measures should be implemented – has it does not enable one to identify and rank the noise sources – and it does not enable one to predict the noise impact of a new factory or of this or that noise control action on an existing installation. Other non negligible aspect consists on the difficulty that "traditional" noise assessments have in presenting results which are easily apprehended by non specialists. This makes it difficult an effective communication of the results attained by noise control programmes to the potentially interested publics, such has the neighbouring communities, governmental agencies, environmental inspectors and auditors, shareholders, insurance companies, municipalities, environmental NGOs. Thus, all the effort and investment put by the organization on reducing its noise emissions is often not recognized by those interested parts, loosing the opportunity to enhance the image of the company.

The development of computer modelling techniques that simulate the acoustic emission and propagation, enables one, in our days, to model with good accuracy and reasonably fast, the most complex scenarios of noise generation and propagation [1]. The results are normally presented in the form of coloured noise maps, each colour corresponding to a given interval of noise levels, typically in steps of 5 dB. Above all, such a model, if correctly developed, enables one to get a true noise monitoring and management system, from which it is possible to rank noise sources, extract the individual contributions of each noise source to any given receiver, update the information whenever changes are introduced in the factory, and establish detailed noise control action plans and predicting its results. Difference maps can also be easily extracted from such a model, in order to depict *before vs. after* maps, *total noise vs. background noise* maps, or *scenario 1 – scenario 2* maps, etc.

The need for an industrial noise map can come up to on a wide range of situations: environmental impact assessment for the installation of a new factory or for changing an existing one, environmental license such as under IPPC regulations, complaints from neighbours, certification under ISO 14000 or EMAS, where a full demonstration of compliance with noise regulations is required [2], [3]. In certain cases, such as industrial parks, the aim can be to control noise build up during the successive installation of new industries in the park, which can be done by establishing noise quota for each lot in the park [4], [5].

Whichever the reason, the number one aim on producing a noise map – and above all the acoustic model on which it is based – should be to get a useful tool which will enable one to correctly evaluate a noisy situation, be it already existent or planned for the future, and study what the best solutions are to comply with given noise limits around the plant. By ranking the sources and predicting the practical outcome of any scenario, one can effectively optimize the investment in noise control actions.

2 General methodology for noise mapping of industrial plants

The general methodology for noise mapping of industrial plants can be resumed as illustrated in Figure 1.

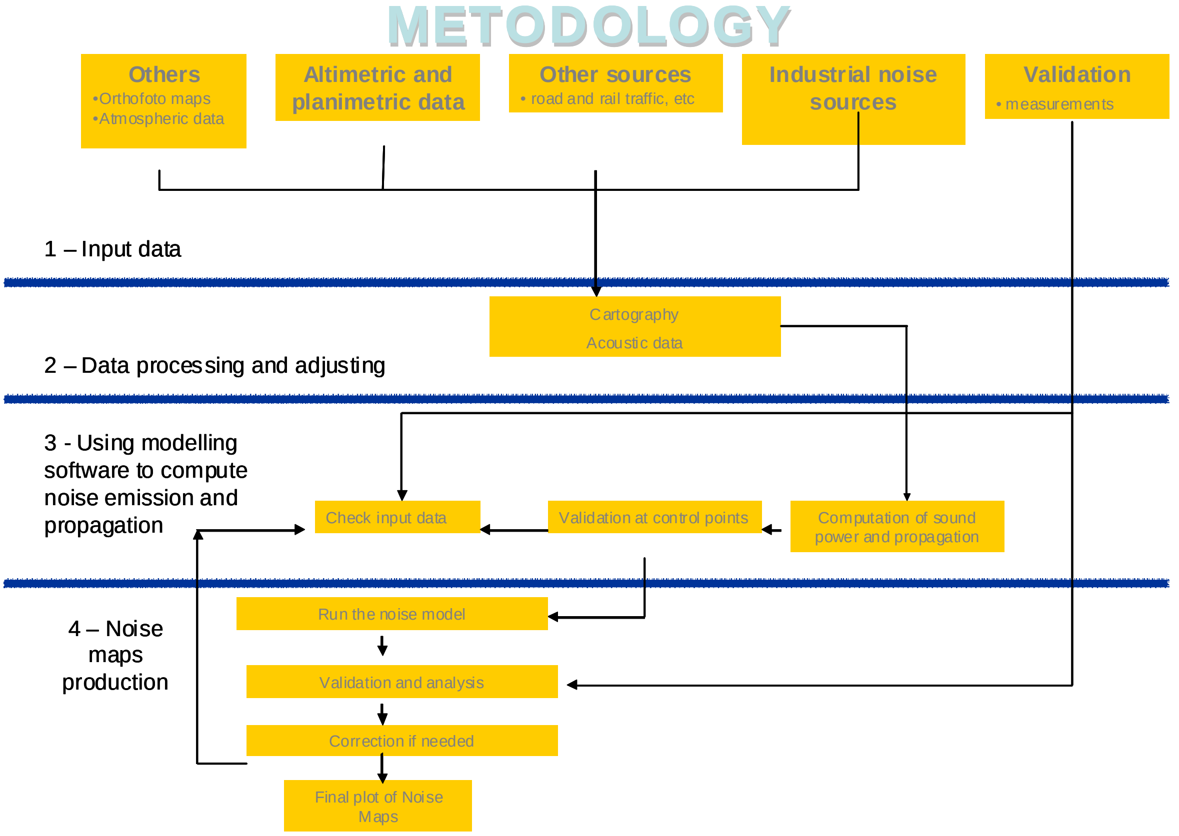

Figure 1 – General methodology for noise mapping of industrial plants.

Obtaining correct input data is, as in any model, the most critical part of the job: the “garbage in, garbage out” expression fully applies here.

Moreover, in industrial noise mapping projects, this is also the hardest part of the job, as very seldom one has access to accurate digital 3D drawings of the plant or, even less, to adequate acoustical data such as sound power level or directivity of the noise sources. Therefore, in most cases of existing plants, one must get all these crucial data the “hard way”, which means:

- Actually spending several weeks on site in order to understand, as deeply as possible, how the industry actually works;
- Getting close to all sound sources in order to measure its noise appropriately (see figure 2);
- Draw by scratch all industrial buildings to insert them into de model;
- Decide how to model each noise source;
- Accurately position them in the drawings in order to be able to insert them at their right places in the model.

It is worth noting that the sources can easily add up to more than one hundred and, sometimes, can come close to a thousand. Also, for interior sources, one has often to estimate, or actually measure, the transmission loss of the building elements involved in the in-out propagation process.

Figure 2 – Getting input data for the acoustic model of a factory: close field measurements.

After collecting all required data, this is introduced in the model and this usually means many adjustments, both for the geometrical data – by checking all information, taking advantage of 3D visualization capabilities of modern noise modelling software, such as CadnaA v3.7 – and for the acoustical data – generally by running calculations at a number of control points corresponding to real points where validation measurements have been taken, and comparing the measured versus calculated values. This is an iterative process which normally means going back into the field to check out doubts, make new measurements and have meetings with engineers from the factory to verify that this or that machine has been running on its normal condition, etc.

Source noise data is normally introduced in the model in the form of octave band sound power level, accounting for directivity and for % working time for each reference period of the day, if relevant for the project. When data comes from actual measurements on site, either sound power levels have been actually taken (e.g. using sound intensity measurements) or, as is normally the case, an estimation of the sound power level is made from pressure measurements close to each source, taking into account its mounting conditions, the presence of reflecting surfaces or other machines nearby and performing a validation process by comparing measured versus calculated noise levels at positions further apart from the source. In fact, full sound power determination for each source according to standards such as the ISO 3740 series, or ISO 9614 is generally out of the question, except in some special situations, such as checking a new machine during set up process or start up of a new factory, and the like.

Simplified methods are therefore used, and care must be taken to ensure one makes the right simplifications and that the validation procedure is extensive enough so that your successive iterations can make the model converge into an accurate acoustic model. This validation process normally encompasses two steps:

- Source validation (figure 3): where single sources or small groups of sources are validated by means of checking measured against calculated values on a set of receivers at intermediate distances, not too close but not too far away from the sources which are being validated, normally inside the plant perimeter, but in the acoustic far field of each individual source;
- Full model validation (figure 4): where the entire plant, with all its sources, is validated by means of checking measured against calculated values on a set of receivers far away from the sources, typically outside the plant perimeter and sometimes close to sensitive receivers, such as neighbouring dwellings.

When it is possible (or it just happens) to stop some machines or groups of machines, one can take advantage of that to facilitate the process of getting and validating noise data.

Figure 3 – Source validation: measurements within the factory but not too close to the sources.

Figure 4 – Model validation: measurements outside the factory, often close to sensitive receivers.

Of course, when dealing with a project for a new factory, things work out differently, and one has to try hard to find acoustical data from suppliers of all types of machines or, when unavailable (as happens too much often), rely on available literature, databases of similar equipments, calculations based on machine parameters or, sometimes, try to find similar equipments running and just going there and measure it.

In any case, an important decision to be taken is on how to model each noise source. There are three basic types of sources which one can introduce in the model (see figure 5):

- Point sources – adequate for small sources, such as fans, or larger sources, with well balanced dimensions, sitting away from relevant receivers;
- Line sources – adequate for linear shaped sources, such has piping, conveyors, as well as moving sources paths;
- Area sources – can be vertical, such as openings in a building, noise radiating façades, or very large machines, or horizontal, such as a roof, or a number of fixed or moving sources distributed on the ground.

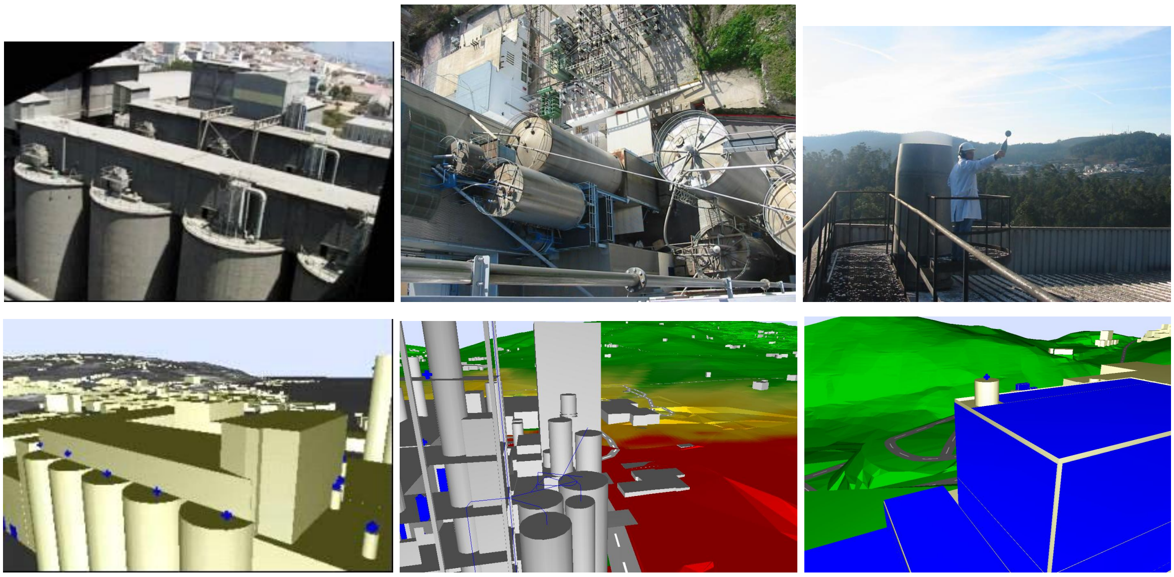

Figure 5 – Examples of sources modelled as (from left to right): point sources – fans on top of deposits, chimneys; line sources – high pressure pellets transportation pipes; plane sources – light metal façades and roof, openings.

The way calculations are made by modelling software such as CadnaA, can be set up to comply with different methods and standards. The most common for industrial sources is the method of ISO 9613 [6], which details we will not go into here. One must also configure correctly a number of software parameters, related with the calculation configuration, such as the ***maximum search radius***, ***minimum distance source to receiver***, ***maximum reflection order***, ***minimum distance receiver-reflector***, ***reference time***, with the grid calculation (for noise maps), such as ***receiver spacing*** and ***receiver height***, or with each source in particular, such as ***single band*** or ***spectrum***, ***directivity***, ***geometry***, and type of noise levels input to the source (e.g. L_p measured at a certain distance outdoors, L_i impinging on a façade from the interior side, etc.).

The hard work involved on building and validating the acoustical model of a large industrial plant is highly compensated when one, finally, gets the final model to produce results which make sense and match the reality. It is then that one can start taking advantage of the model for practical applications, such as source ranking, calculation of individual source contributions to the total noise at any given receiving point, evaluation of different scenarios of noise control actions to propose an action plan and, of course, fully running the model to get noise maps, creating calculation grids which one can even use for further grid operations, such as arithmetic or logarithmic addition or subtraction.

3 PRACTICAL EXAMPLES OF APPLICATION

3.1 Chemical plant

This noise mapping project came from the need of the company to renew its IPPC Environmental License, having indications that it was not fully complying with noise limits imposed by the Portuguese regulations. Therefore, a comprehensive noise source survey was carried out, estimating its octave band sound power level from sound pressure level measurements close to each source. As happens with most process industries, most relevant sources are located outdoors and they run 24 h a day. Input data has been appropriately validated, according to the methodology described above: source validation followed by model validation – this was not particularly difficult in this case, due to the fact that the plant is located in the countryside, away from other noise sources, except for a national road, but with sparse traffic. However helpful this may be for model validation purposes, the fact that background noise is very low does not help when it comes to noise control requirements as, according to regulations, one must reduce plant noise down to the background level. The present regulations, however, do imply that, in case background level is lower than 42 dB(A), which was the case at most sensitive receivers in this project, the limit for particular noise from the factory, at any time, is also 42 dB(A), including the correction factors for tonal components (+ 3 dB(A)) and/or for impulsive noise (+ 3 dB(A)). From the acoustical model, a source ranking has been performed, identifying the sources which generate more noise to the sensitive receivers, which in this case are just a few isolated houses, located to the opposite side of the national road, as can be seen on Figure 6

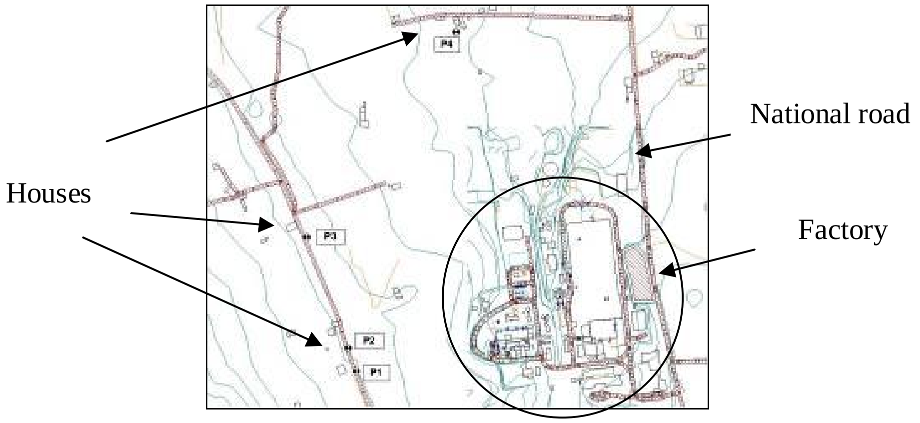

Figure 6 – Location of the factory, road, houses and corresponding measurement points P1, P2, P3, P4.

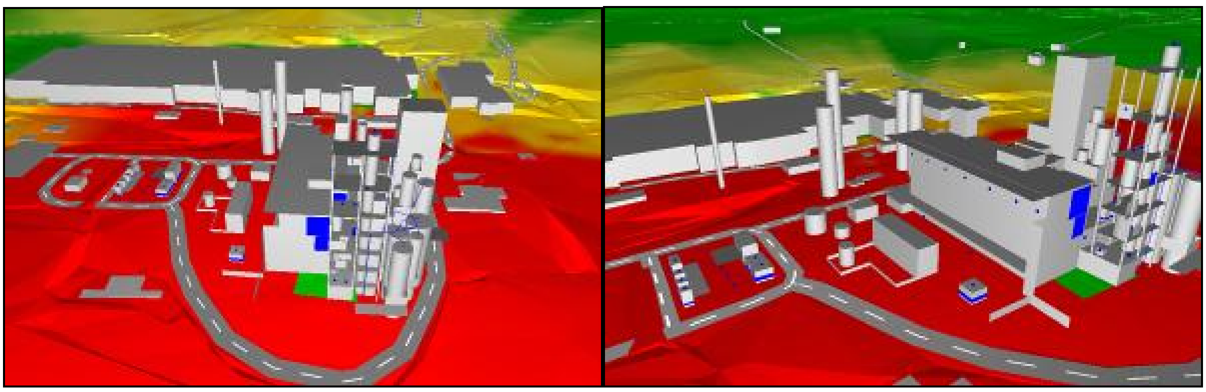

Figure 7 –3D drawings of the acoustical model, with projection of the noise ma pinto the terrain.

3.2 Food industry

This example is almost the opposite of the chemical plant, as it is a traditional old plant, located right in the middle of the city, with residential buildings all around, the background noise levels are high and most noise sources are inside buildings, except for chimneys. Although the factory does not actually stop at night, some sections of it do stop, therefore reducing its activity, and noise generation, during night time. The project started due to a complaint from a neighbour leaving near the factory. The project consisted of developing the acoustical model, produce noise maps of present situation to assess the noise impact and communicate it to the Municipality, specify a noise control action plan, implement it and measure the final results, updating the noise map in the end.

Two types of sources were identified as relevant to the noise emission: interior sources, which radiate noise to the outside through the vast number of windows, and chimneys, located above the roofs. The first were not taken individually – the approach has been to measure noise impinging on the windows from the inner side, and use the CadnaA feature "L_i from interior sources" together with the transmission loss of the windows to calculate the sound power lever per unit area radiated to the outside by vertical area sources, which were used to model the windows. The latter were measured and inserted in the model one by one as chimney sources, with a frequency dependent directivity, simulated by CadnaA from the known velocity and temperature of the gas flow at each chimney.

In this case, apart from the regular validation process, attention has been focused at the most critical receivers, namely at the house of the complainant, out of which window the microphone was mounted. Continuous long term measurements were taken, for several days including week and weekend days, using a PC-based noise analyser, with audio recording. This helped in identifying noise sources, also enabling the filtering out of background noise events such as car pass-by during the more silent periods, such as night and weekend. Both the model and the measurements agreed that the number one sources were noisiest chimneys located above the building closer to the complainant house, followed by windows of the noisiest floors of the factory buildings with façades directed towards the afore mentioned house.

An action plan was specified in two steps, the first of which has been already implemented. Control measurements have been taken, including another long term measurement at the complainant window, which show a clear noise reduction, within the expected from the model. Next figures illustrate this case study.

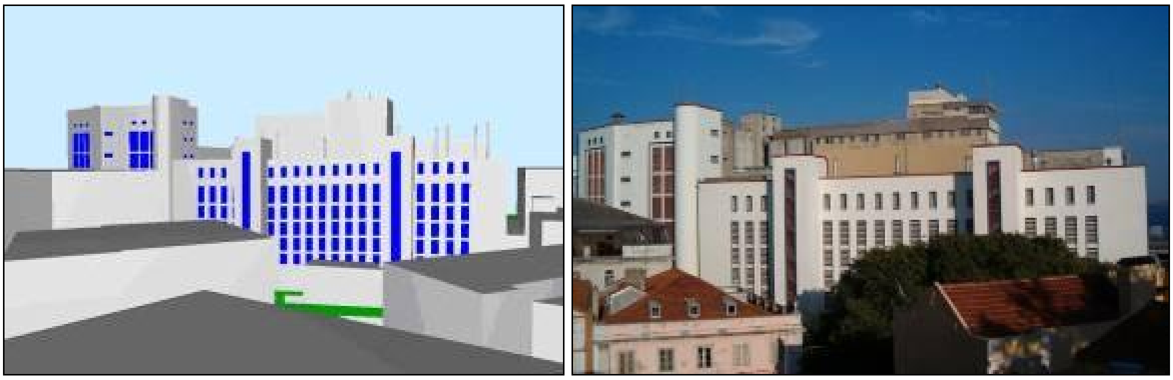

Figure 8 – 3D view of the CadnaA model and corresponding photo, both views taken from the window of the complainant's house.

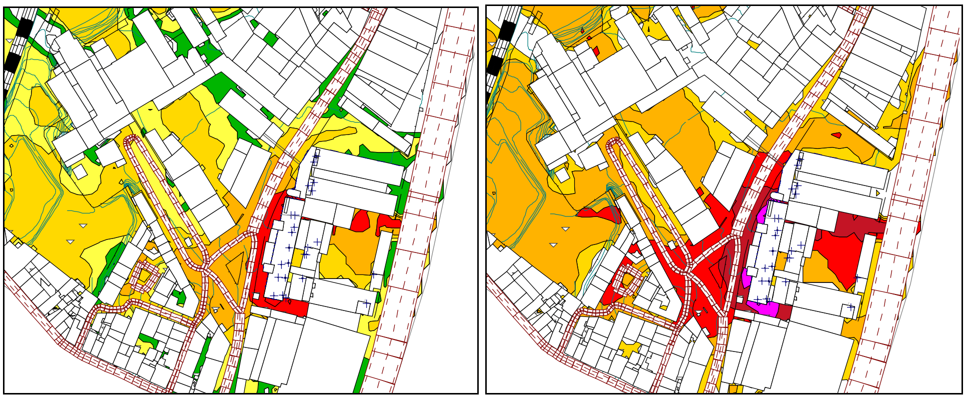

Figure 9 – Noise maps for noise indicators L_n (left) and L_{den} (right).

3.3 Foundry

This Project consisted on the production of Noise Maps in the context of an Environmental Impact Study for the expansion of the Foundry, which needed to increase its production capacity, for a number of scenarios: present situation, future situation with no noise abatement measures and future situation with noise abatement measures. The specification of these noise abatement measures was also part of the project. The present situation noise map had already been produced in the past, although it had to be updated to the new Portuguese noise law, and it was complying to the regulations. As the foundry was going to enlarge and new equipments were to be installed, the aim of the company was to study the problem in order to guarantee that it would still comply with the noise limits after the expansion project has been concluded.

A complete survey was carried out of all the changes which would take place, including new equipments, new layouts and new buildings. In this case, sound power levels from most new equipments were available and were introduced in the model. Noise levels at critical points were calculated and source ranking was made in order to identify which noise sources needed to have special noise control conditioning measures prior to its installation, which could include relocation relative to the initially planned, in order to maintain full compliance with the noise limits. Next figures depict noise maps without and with the noise control measures as well as a map of differences, obtained by grid subtraction of the noise maps of the two scenarios.

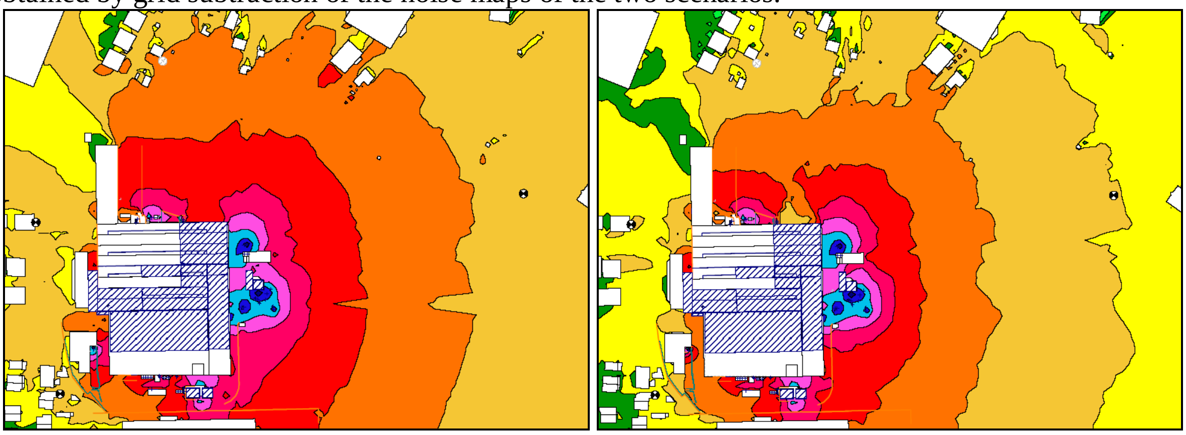

Figure 10 – Noise maps of the foundry after the expansion without (left) and with (right) noise control measures.

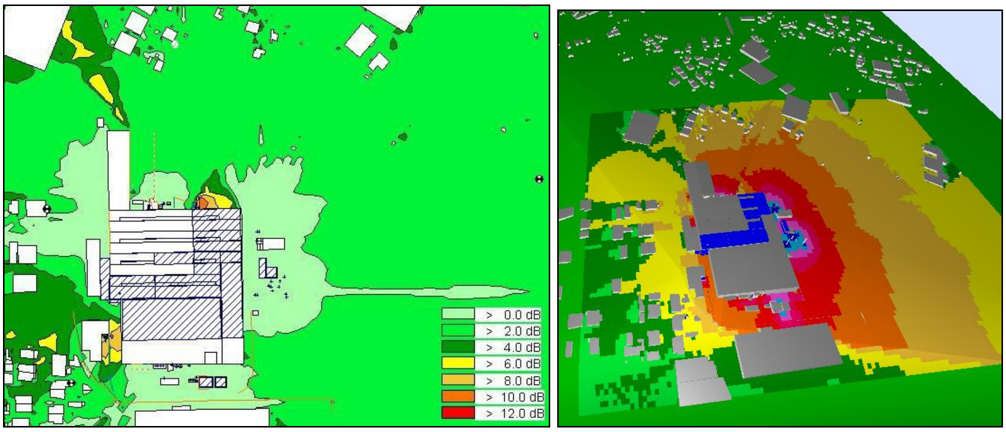

Figure 11 – Map of differences (without minus with noise control measures) and 3D visualization of the noise map with the noise control measures.

3.4 Cement industry

This example relates to a large cement factory which was starting the implementation of a large investment plan on its production lines which consisted basically on the replacement of three existing lines, which were old and ineffective, by a new production line, with a new kiln, with higher production capacity. Due to lack of space and presence of an urban agglomeration nearby, it was a complex operation and noise was one of the major issues as it should comply with ever more stringent regulations. Therefore, a noise mapping project has been carried out, which enabled the simulation of three main stages: present situation, transition situation and final situation with the new production line. It was shown that, at present, the factory is not complying with legislation and, although a noise reduction is predicted with the new layout of the factory, it has been shown that there is a high risk of not complying with the regulations. In this context, a noise control plan was studied, aiming at the full compliance with noise limits when the project is finished, i.e., at the final stage with a single production line (see Figure 12).

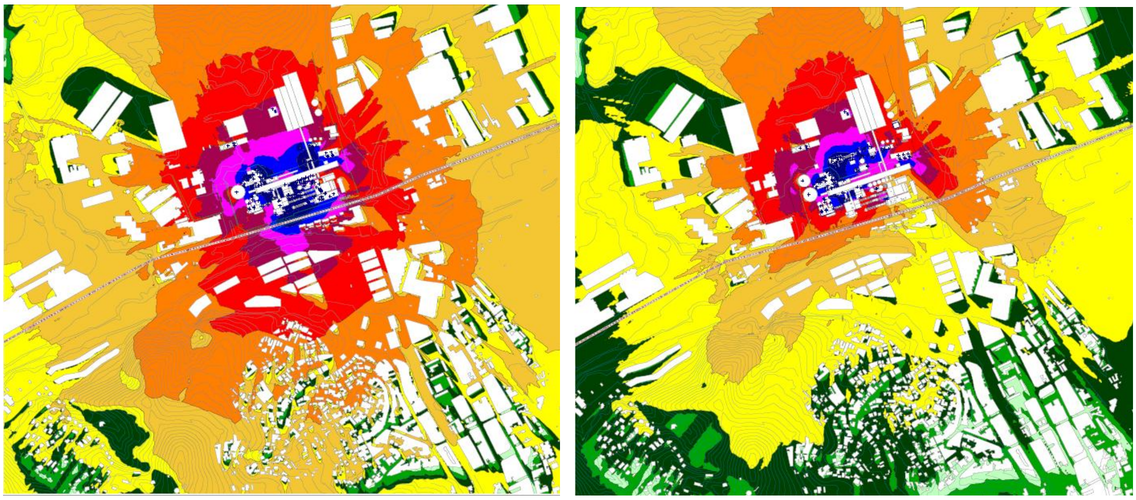

Figure 12 – Noise map of the present situation (left) and of the future situation with noise control measures (right).


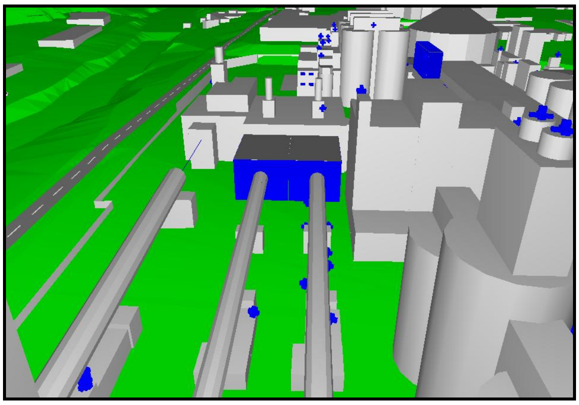

Figure 13 – View of the three cement kilns at present: photo (left) and model (right).

3.5 Wind farm

The aim of this study was the presentation of a noise map for the future situation, in the framework of the required permits for future installation of a wind farm, and assessment of its noise impact by comparing the future noise levels with those of the situation without the implementation of the project. Input data, apart from the cartography in vector format and orthophoto maps, were the frequency of occurrence of different wind velocities for each wind generator, and the wind rose characteristic of the surroundings of the plant.

Noise measurements were taken at different times of day and on more than one day, in order to get a good representation of the initial acoustical situation. From the acoustical model, the noise from the wind generators were calculated, at the measurement points and at all the surrounding points, by means of a noise map. In this particular case, due to the proximity of some sensitive receivers to some of the initially planned generator locations, these had to be changed to comply with noise limits and avoid future problems when the wind farm starts to operate. Next pictures illustrate this example.

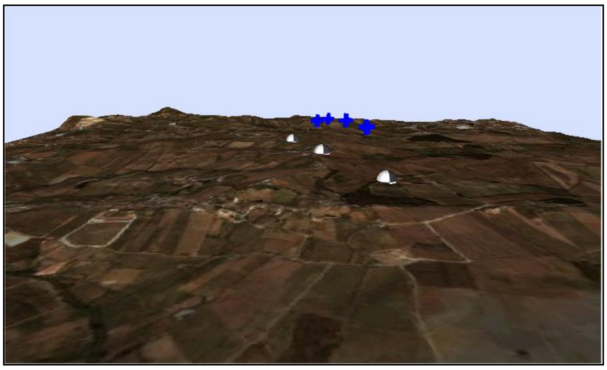
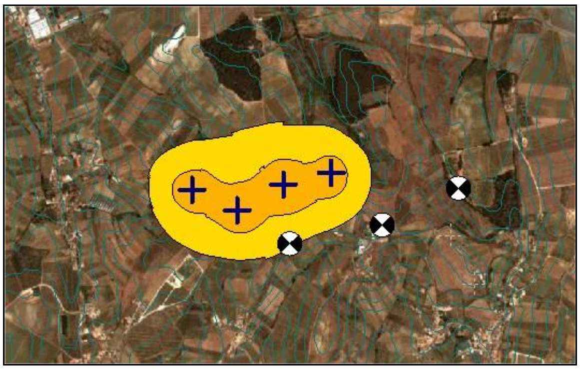

Figure 14 – 3D view of the model (left), showing a superposition of the orthophoto onto the terrain; and noise map in terms of L_{den} (right) .

4 Conclusions

Computer acoustic models of industrial plants and noise maps are powerful tools for noise assessment and management, with very interesting applications both at the design stage as well as when the plant is already running. Not only it is an excellent way of making evidence of compliance to noise regulations, when this is the case, but it is even more useful when something has to be done to achieve such compliance. Enabling one to easily make a source rank, and simulate any scenario, one can be very effective in presenting noise abatement action plans and help the industries making the right noise control investments which, in many cases, are not at all negligible. Therefore, although it takes normally a large amount of work to produce the acoustical model, which of course has its own cost, it is well worth doing it whenever a new industrial plant is to be built or changed, as well as when a complex existing plant needs to produce evidence of noise compliance or is having noise complaints from neighbours.

References

[1] W. Probst. Modelling of Industrial Plants in the Framework of Sound Immission Plans. *Proceedings of InterNoise 2000,* Nice, France, 2000.

[2] L. C. Santos; P. Valério. O Mapa de Ruído como Ferramenta de Gestão Ambiental na Indústria. *Proceedings of Acústica 2004*, Guimarães, Portugal, September 2004.

[3] Instituto do Ambiente – *Directrizes para a Avaliação de Ruído de Actividades Permanentes (Fontes Fixas).* Abril 2003

[4] W. Probst; B. Huber. Noise Quota for Industrial Sites – an Application of Noise Mapping Projects. Proceedings *Proceedings of InterNoise 2000,* Nice, France, 2000.

[5] L. C. Santos. Noise Mapping and Noise Quota Application to an Industrial Park. *Proceedings of Acústica 2004,* Guimarães, Portugal, September 2004.

[6] ISO 9613-2:1996. *Acoustics - Attenuation of Sound During Propagation Outdoors - Part 2: General Method of Calculation.* International Organization for Standardization