4 DESIGNING OF NOISE PROTECTION SYSTEMS IN INDUSTRIAL ENVIRONMENT

4.1 Introduction

The conduct of manufacturing processes in heavy industry is often connected with excessive acoustic emission to the environment and consequently with problems related to the impossibility to meet acoustic standards within residential areas situated in the vicinity of big industrial plants. Therefore, it is necessary to limit excessive acoustic influence, which is usually quite difficult due to the necessity of having specialist knowledge as well as the cost and scope of acoustic protection systems' implementation. This article presents an example of a reasonable approach to designing of acoustic protection systems in industry (reducing industrial plants' acoustic emission) which consists in taking present acoustic influence of a plant into consideration, specifying the right order for the protection systems' implementation and preparing the right concept as regards means of noise reduction ensuring the required acoustic effect. The presented approach to the issue of noise reduction also makes it possible to plan implementations optimally, giving consideration to the order of protection systems' development, the implementation's time and cost as well as to the acoustic effect obtained.

4.2 Reasonable approach to the issue of industrial noise emission reduction

It is usually necessary in industrial practice (particularly in heavy industry) to reduce the environmental noise emitted from a relatively vast area with a great number of various noise sources, such as: industrial facilities, or sections of the facilities' elevations, having insufficient acoustic insulation, fans, blast machines, engines (drives), compressors, wet or dry fan coolers, etc. In such a case the main task is to specify the scope and order of attenuation works, giving consideration to the ecological effect which may be obtained (the ecological effect is defined as the decrease of LAeqD or LAeqN indicator in dB in a measurement point located within the area protected from noise) as well as to the cost of the protection systems' development. The difficulty connected with fulfilment of such a task is usually connected with the lack of possibility to use measurement methods in order to specify the so called 'grade of source importance'. Usually all noise sources work simultaneously on a plant's premises and it is impossible to cease the production process in order to carry out an experiment consisting in subsequent starting of respective noise sources and measuring their influence on the noise observed in control points. This is caused by high costs of production interruption or the impossibility to stop the production process due to a special nature of a particular technological process. It is often the case that it is even physically impossible to take such actions as the work of one source enforces the work of the remaining sources (process lines).

Another impediment is often high background noise connected with the presence of neighbouring industrial plants, main roads (e.g. provincial or national roads and highways) or railways. Such conditions practically prevent taking precise measurements of background noise – especially when an industrial plant works continuously.

The problems specified above make it practically impossible to:

- Determine the correct number of sources to be attenuated,
- Specify the necessary reduction of the attenuated sources' acoustic power,
- Specify the correct sequence of attenuation works' implementation,
- Select the means of noise reduction properly,
- Evaluate efficiency of the attenuation works and their influence on the environmental effect,
- Estimate the cost of noise protection systems' implementation,
- Prepare a schedule of works and expenditures for the planned implementations.

An alternative for measurement methods which are difficult to apply are calculation methods based on the model of noise propagation described in PN ISO 9613-2:2002 standard: Acoustics. Attenuation of sound during propagation outdoors. General method of calculation. The use of the aforementioned method makes it possible to conduct a comprehensive assessment of an industrial plant's acoustic influence on the environment as well as to determine the influence of respective sources of noise on the level of sound observed in a control point. That is why, in order to prepare the attenuation works' strategy and to specify the necessary noise reduction of respective sources it is recommended to perform the following actions:

- To list the main sources of noise located on the premises of an industrial plant, including surface sources, point sources and line sources;
- To make acoustic measurements of noise sources on the premises of an industrial plant in order to determine their acoustic power in an octave frequencies' function in accordance with PN-EN ISO 3746:1999 or pn-EN ISO 3744:1999 as well as source directivity;
- To develop a geometric model of the plant (3D) on the basis of 1:1000 scale maps. The model must contain all the elements (buildings, sheds, slopes, embankments, screens, etc.) Exerting influence on sound propagation in the environment;
- To develop an acoustic model of an industrial plant containing all the significant noise sources: point sources (fans, air bleeding, chimneys, etc.), vertical surface sources (elevation of workshops, windows, big intakes, etc.), horizontal surface sources (roofs), line sources (conveyors, car or railway transportation way, etc.), and their acoustic specifications,
- To calculate the level of sound transmitted outside from the plant's premises – determination of the so called acoustic map of a plant's influence, on the basis of a calculation model specified in PN ISO 9613-2:2002,
- To indicate noise measurement control points in the environment located within areas subject to protection against noise, i.e. Within the area where a plant's acoustic influence ought to be limited,
- To calibrate the calculation model, to estimate maximum errors of the calculation model in noise measurement control points,

- To measure the level of sound in control points in accordance with reference methodology specified in the Regulation of Minister of Environment of 4 November 2008 on the requirements for conducting measurements of emissions (Journal of Laws, 2008, no. 206, item 1291),
- To specify the share of respective noise sources in control points according to algorithms implemented in the acoustic software (CadnaA, SoundPlan, HPZ, etc.) and to indicate the sources responsible for exceeding the permissible noise values in the environment,
- To identify noise sources to be attenuated, to specify the optimal sequence of noise protection systems' implementation and to determine the required minimum reduction of the noise source defined as the decrease of the acoustic power in db after its attenuation,
- To prepare the concept of attenuation of respective noise sources or groups of noise sources, to select the type and kind of the noise reduction means (acoustic screens, casings, silencers, etc.), to prepare the concept of acoustic adaptation of halls or rooms, etc., to specify the required acoustic parameters of the designed means of noise protection,
- To analyse the effectiveness of the designed noise protection means with the use of calculation methods in order to determine the acoustic result which may be obtained in a control point and to compare the efficiency of various sound protection systems,
- To agree on the prepared concepts of sound protection means with the purpose of considering the specific nature of the used machines and devices, to analyse the possibility of implementing the designed solutions in certain conditions, to take the necessity of providing daily and periodical services into consideration, to increase ergonomics of the suggested solutions, etc.,
- To specify the range of the plant's acoustic influence in the form of a line of the same sound level after implementing the suggested protection systems,
- To make an acoustic design of the protection systems: to select the existing geometric features of the sound protection systems, to select typical or non-standard (specialized) sound insulation and/or sound absorbing materials, to specify the required technical parameters of the applied materials, to prepare illustrative documentation of the noise protection systems, to list the guidelines and instructions for the company implementing the noise protection systems,
- To prepare construction documentation and/or detailed design documentation of respective noise protection systems, to prepare construction design (structure, architecture, area development) in case of acoustic screens or acoustic casings bound permanently to the ground,
- To conduct an estimated analysis of the cost of suggested technical solutions' implementation on the basis of current market rates of materials and services or to prepare a detailed investment cost estimate,
- To implement the noise protection system and to take as-built measurements.

4.3 An example of setting the sequence of attenuation works

Effective reduction of industrial plants' acoustic influence is possible only thanks to a complex approach to this issue. Such a complex approach includes all the works connected with the main sources' attenuation – from the sources' identification, through design preparation and up to implementation of the noise reduction means.

An example of evaluation of an industrial plant's acoustic influence, preformed in accordance with the principles specified in Section 2, has been presented in fig. 4.1 and fig. 4.2 presents the prepared geometric and acoustic model of the plant, taking all main noise sources located on its premises into consideration. This model was developed with the use of CadnaA software provided by DataKustik company.

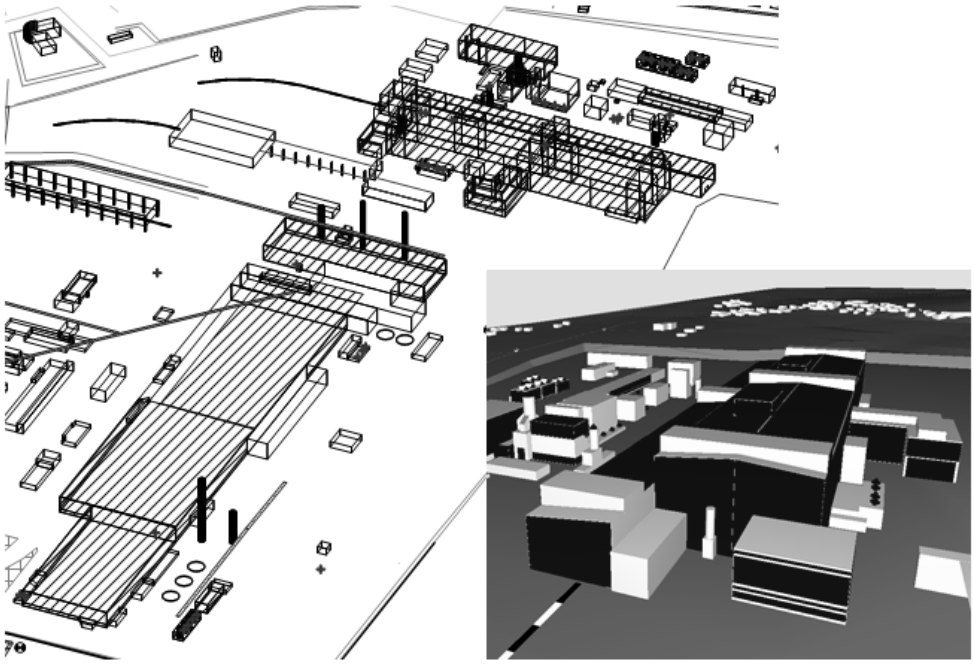

Fig. 4.1 Geometric and acoustic model of an exemplary industrial plant

After the acoustic model had been prepared and calibrated, calculations were made in order to specify the present range of the plant's acoustic influence and to identify the influence of respective sound sources on the noise observed in control points. Fig. 4.2 a presents an acoustic map depicting the plant's acoustic influence on external environment before commencement of the attenuation works. Then, in selected control points located within the areas protected from noise, the role of respective sources in the total noise emitted from the plant's premises was specified. An exemplary specification of share of the level of sound coming from respective sources in the control point has been presented in fig. 4.2 b. The diagram depicts the suggested sequence of attenuation works established according to the maximum acoustic effect criterion.

Preparation of the attenuation works' schedule requires giving consideration to the correct sequence resulting from the influence of the main sources on the observed noise and analysing the possibility of performing works in the attenuated facility as well as analysing the schedule of repairs for a particular facility and considering the possibility of changing

the technology into a quieter one, in addition to considering the plant's financial capacities. However, the diagram presented in fig. 4.2 b is the basis for preparation of the implementation works' schedule. Moreover, the necessary noise reduction for a particular source is also determined on the basis of the aforementioned diagram as well as the threshold value of the sound level which should not be exceeded by any source in a particular observation point. The threshold value depends mainly on the number of dominant sound sources and on the value of the sound level admissible in a control point.

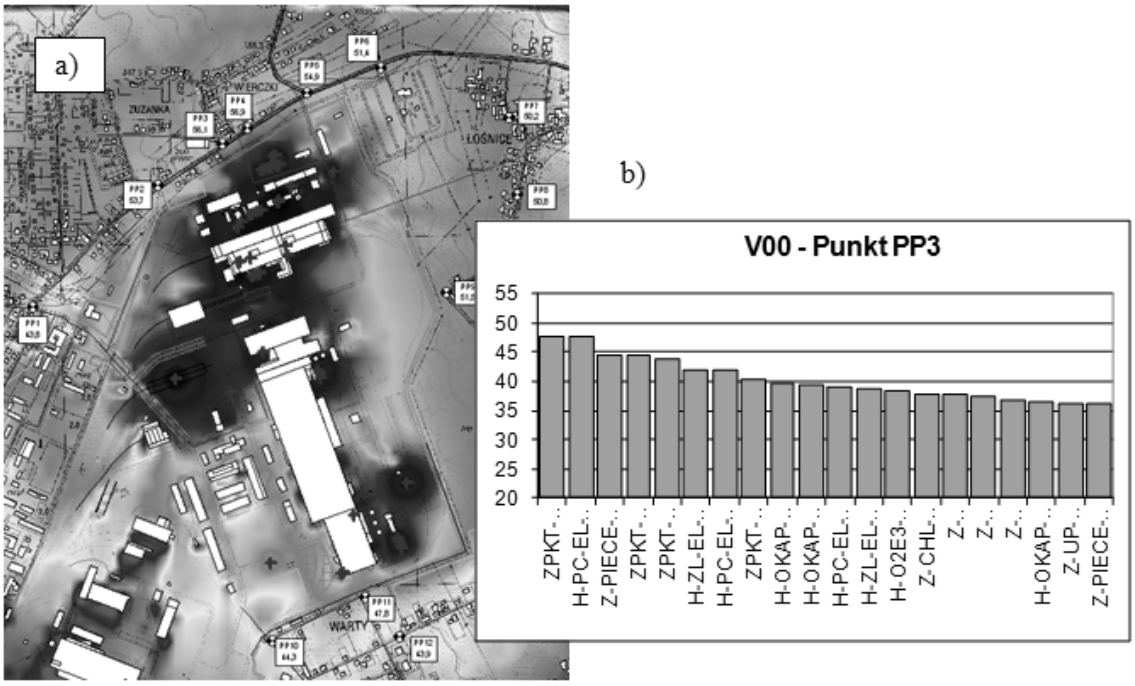

Fig. 4.2 Map of the plant's acoustic influence before any noise attenuation (a) together with a diagram of respective sources' share in the total noise observed in a selected control point (b)

4.4 Designing of noise protection systems

Having decided on the sequence of attenuation works to be performed on the plant's premises, one usually has to answer the question how to perform the attenuation itself, which noise reduction means to apply and what materials to use as well as whether the noise protection system designed by a particular company will be effective. These questions are usually answered by an acoustic design. Its main purpose is to determine the most effective attenuation method of a particular noise source taking exploitation criteria into consideration. The noise protection system's designing stage consists in a very detailed specification of needs and requirements of employees operating the device to be attenuated as well as giving consideration to requirements listed in the operation and maintenance manual. Only after agreeing on the conditions to be met by the designed noise protection system, can one develop the system's concept – it can be a few solutions out of which the best one will be selected. It is important that the acoustic efficiency criterion be taken into consideration as soon as at the stage of devising. The designed solution has to meet the requirements as regards the minimum noise reduction, therefore, it must ensure an appropriate acoustic result defined

as the difference of the sound level in a control point before and after the system's implementation. The noise protection systems to be implemented are only the systems whose acoustic result we are sure of or the ones which give the highest chance of meeting the assumed criteria. Comparing the effectiveness of various noise protection solutions or estimating the acoustic result of a particular selected solution ought to be conducted with the use of calculation methods based on the propagation model described in standard PN ISO 9613-2:2002.

An example of using the aforementioned methods in order to analyse the effectiveness of a casing of a group of centrifugal fans of an electric-arc furnace dust extraction machine has been presented in fig. 4.3. An acoustic design was the basis for determination of geometric and acoustic properties of the casing, selection of the right materials and the method of their assembly and preparation of the construction design (structure, architecture) as well as detailed design of the noise protection system.

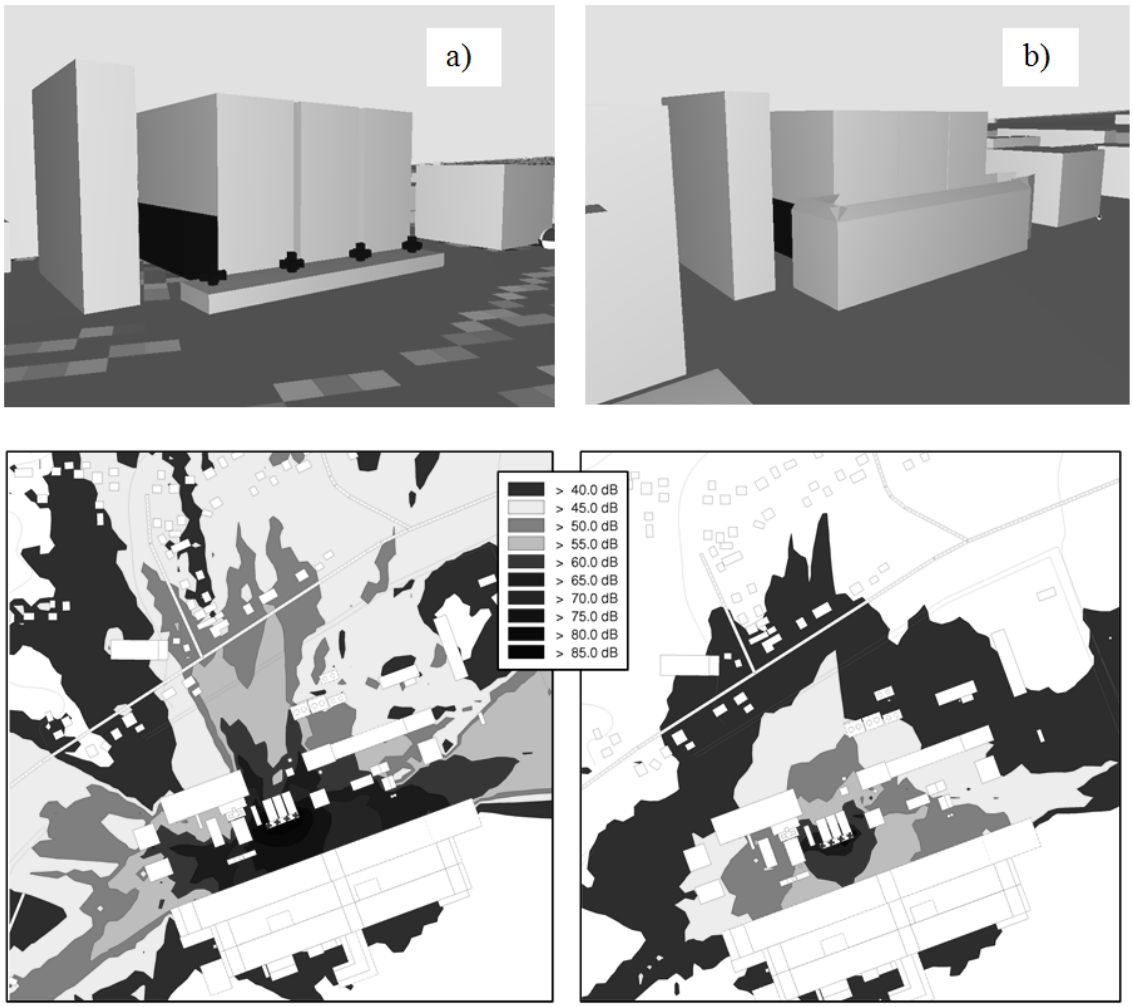

Fig. 4.3 Part of an acoustic design of set of fans:
a) present condition (without the casing)
b) designed condition (with the casing)

c)

Punkt	Poziom dźwięku A w punkcie pomiarowym					
	Stan obecny	E-8m prosty	E-10m prosty	E-10m pochyl	E-12m prosty	E-12m pochyl
P1	77,8	63,4	61,9	61,6	61,1	60,9
P2	74,1	61,4	59,6	59,6	58,6	58,6
P3	65,8	58,4	58,1	58,1	58,1	58,1
P4	63,0	51,6	51,2	51,2	51,2	51,2
P5	51,8	43,4	42,8	42,6	42,5	42,4

d)

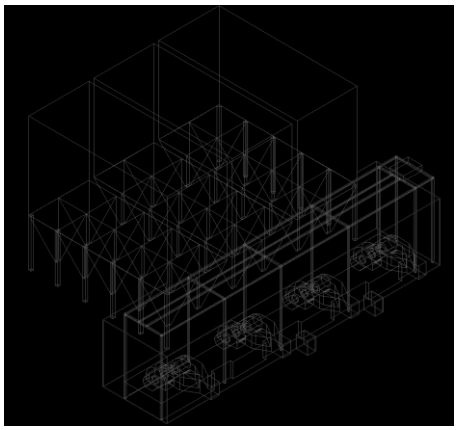

Fig. 4.3 Part of an acoustic design of set of fans:
c) comparison of the sound level in a selected point depending on the casing's geometric parameters
d) one of the acoustic casings' concepts

Fig. 4.4 depicts the said casing after its implementation. Another example has been presented in fig. 4.5. In this case the acoustic design concerned attenuation of external walls elevation of electric melting shop hall. Too low acoustic insulation power of the existing hall's elevations was the main cause of increased noise emission towards residential areas. The concept regarding solving the problem consisted in changing the existing elevations into elevations of significantly better acoustic parameters (Rw and α).

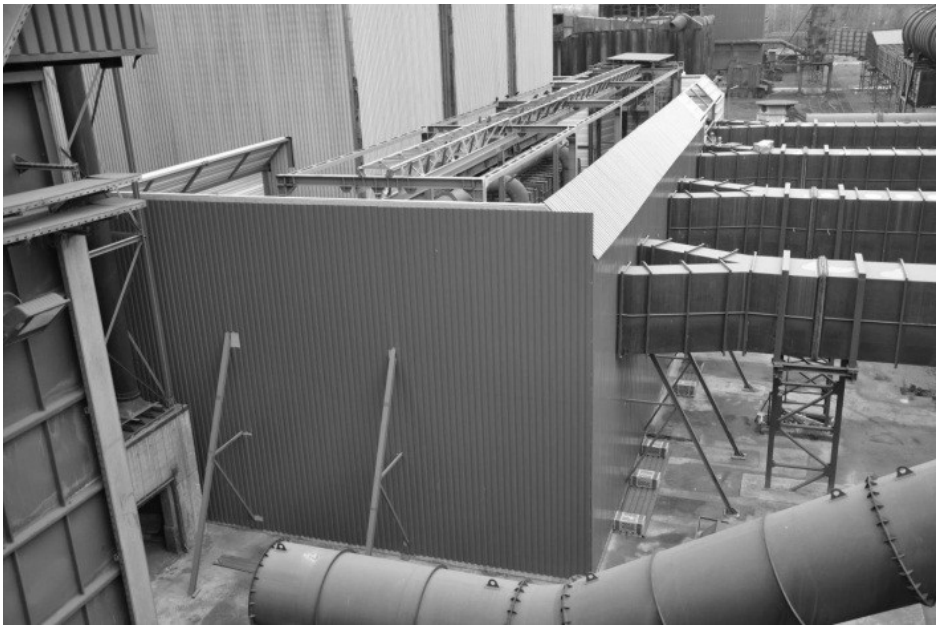

Fig. 4.4 Designed acoustic casing of the set of fans after its implementation

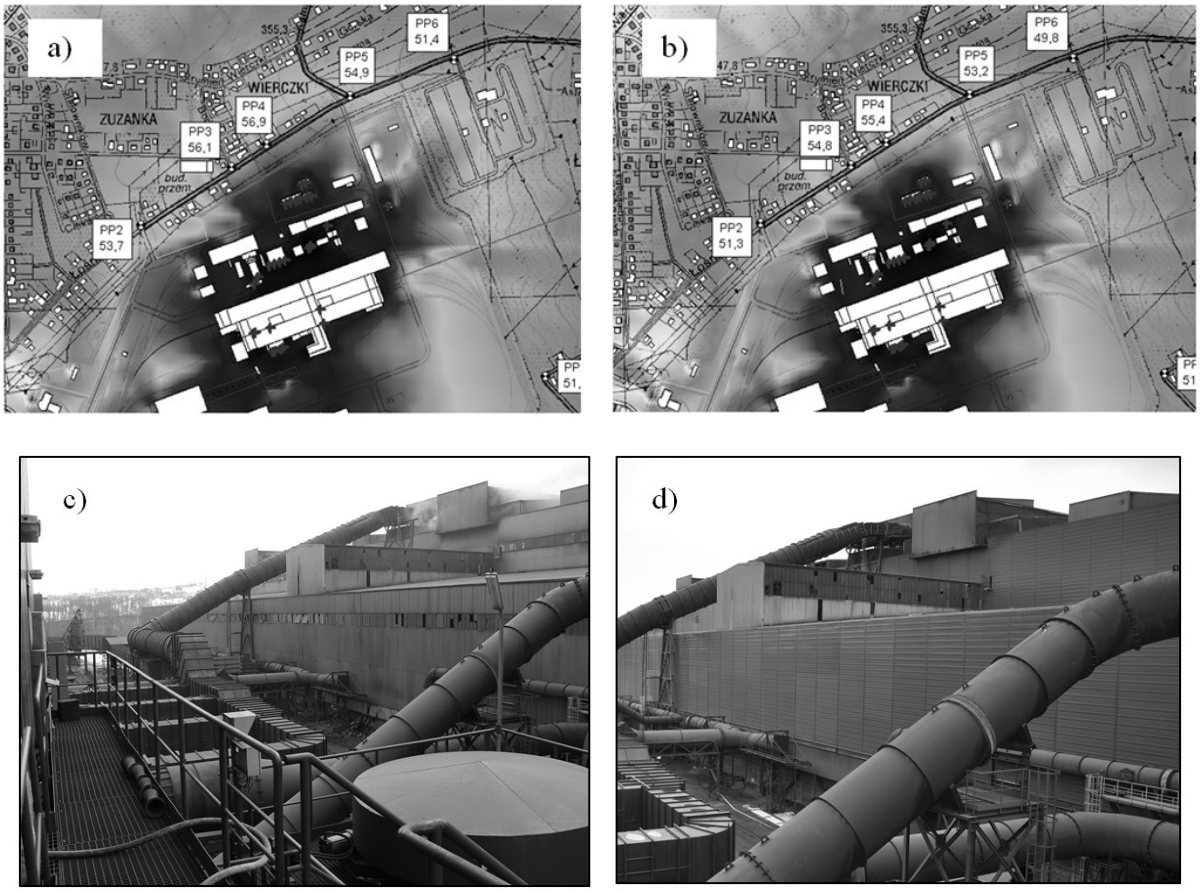

Fig. 4.5 Attenuation of electric melting shop elevations:
a) distribution of the sound level in the environment before attenuation
b) distribution of the sound level in the environment after attenuation
c) electric melting shop elevations before attenuation
d) elevations after attenuation

4.5 Conclusions

The method of noise protection systems' designing presented in this article assumes a reasonable approach to the process of noise sources' attenuation which consists in taking all the acoustic influences and conditions specific for a particular industrial plant into consideration in the whole designing process. Such actions make it possible to specify the scope and sequence of attenuation works, to estimate the works' costs and evaluate the acoustic result which can be obtained, and consequently to rationally plan the tasks connected with noise reduction. As a result, this method allows to design effective means of noise protection and to conduct a conscious process of gradual reduction of the whole plant's noise emission to the external environment.

According to the author's professional experience, an acoustic design is an essential element of the noise reduction means' designing process which definitely cannot be skipped. A properly prepared acoustic design ensures obtaining of the maximum acoustic effect thanks to the use of noise reduction means as well as the right selection of materials and technical solutions guaranteeing durability of the obtained acoustic effect and correct use and exploitation of the attenuated devices.

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