

Cost Effective Approaches to Industrial Noise Control

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Petrochemical and process sites are required to ensure best available techniques are employed to control noise. This can be as a result of permitting requirements, occupational noise exposure, addition of new plant, or changes in operating conditions. Identifying noise control mitigation options for existing industrial sites and demonstrating best available techniques can present engineering challenges and come at a high cost.

This paper presents a roadmap for identifying effective noise control mitigation measures at the lowest cost to industry. It includes considerations for a combined approach to sound power determination and cost-benefit analysis. Techniques include sound power estimation, sound intensity and vibration velocity.

Case studies from recent work on process sites will be presented and include auralisation examples, to demonstrate the real world benefit of the techniques under discussion.

Keywords: Industrial Noise, Environmental Noise, BS4142, Noise Control, Environmental Permitting, Best Available Techniques, Occupational Noise Exposure, As Low As Reasonably Practicable.

Introduction

Over recent decades the negative health impacts of noise pollution and noise exposure have become better understood. This has led to a range of environmental regulation and workplace health and safety legislation which requires noise to be controlled at source.

Petrochemical and process sites are required to ensure Best Available Techniques (BAT) are employed to control noise. This can be as a result of permitting requirements, addition of new plant, or changes in operating conditions. Sites are also required to ensure occupational noise exposure is As Low As Reasonably Practicable (ALARP).

Retrofitting noise control to existing industrial plant can present engineering challenges and potentially high cost, therefore it is important to ensure that the most significant noise polluters are identified along with effective mitigation measures.

This paper presents a roadmap for identifying effective noise control mitigation measures at the lowest cost to industry. It includes considerations for a combined approach to identifying the most significant noise polluters which can reduce survey time and therefore cost. It also presents an approach to cost benefit analysis to assist in identifying the most cost-effective combination of noise control mitigation measures. The focus is on environmental noise emission, however a similar approach can be used to identify noise control in order to demonstrate ALARP.

Noise Concepts

Key concepts for this paper include:

- Sound Pressure – equivalent to the noise level in the air as experienced by humans, or measured at a point in space.
- Sound power – the total acoustic power produced by a noise source in all directions.
- Noise Emission – noise emitted from the industrial plant.
- Noise Imission – noise received at a receptor location.

Noise Policy Statement for England

Although not applicable to the whole of the UK the approach of the Noise Policy Statement for England (NPSE) is a driver for this type of methodology so it is worth mentioning here to provide context.

The NPSE sets out the long term vision of the English Government noise policy, which is to promote good health and a good quality of life through the management of noise within the context of policy on sustainable development. Whilst the NPSE did not seek to change existing policy, the document was intended to aid decision makers by making explicit the implicit underlying principles and aims regarding noise management and control that are to be found in existing policy documents, legislation and guidance. Where existing policy and guidance does not provide adequate guidance then decision makers can go back to the aims of the policy statement to provide overriding guidance.

The "Noise Policy Vision" is to "promote good health and good quality of life through the effective management of noise within the context of the English Government policy on sustainable development". This long term vision is supported by the following aims, through effective management and control of environmental, neighbour and neighbourhood noise within the context of English Government policy on sustainable development:

i. avoid significant adverse impacts of health and quality of life;

ii. mitigate and minimise adverse impacts on health and quality of life; and

iii. where possible, contribute to the improvement of health and quality of life.

The aims of the policy differentiate between noise impacts on health (e.g. sleep disturbance, hypertension, stress etc.) and noise impacts on quality of life (e.g. amenity, enjoyment of property etc.). The aims also differentiate between "significant adverse impacts" and "adverse impacts". The explanatory note to the NPSE (paragraph 2.21) clarifies that a significant adverse impact is deemed to have occurred if the "Significant Observed Adverse Effect Level" (SOAEL) is exceeded. An adverse effect, on the other hand, lies between the "Lowest Observed Adverse Effect Level" (LOAEL) and the SOAEL.

In assessing whether a development should be permitted, there are therefore four questions that should be answered, with reference to the principals of sustainable development, viz. will the development result in:

a. a significant adverse impact to health;

b. a significant adverse impact to quality of life;

c. an adverse impact to health; or

d. an adverse impact to quality of life;

If the answer to question a. or b. is yes, then the NPSE provides a clear steer that the development should be viewed as being unacceptable (item i. above).

If the answer to question c. or d. is yes, then the NPSE provides a clear steer that the impact should be mitigated and minimised (item ii. above).

Environmental Noise Modelling

Environmental noise can be evaluated by the specific noise level due to the industrial plant received at chosen receptor locations. Noise limits will often be defined with reference to noise levels at the closest sensitive receptor.

All the individual noise sources on an industrial plant combine together to give the cumulative noise emission from the plant and contribute to noise levels at receptor locations. In order to select the most appropriate noise control solution an understanding is required of the most significant contributors to noise at receptor locations. It is already possible to predict to a good level of accuracy how sound is attenuated as it propagates through the air and around obstacles, for example, if the noise emission from an industrial plant can be determined, it is possible to predict the resulting noise imission at receptor locations. This is useful to understand as measurements made directly at receptor locations can be influenced by extraneous noise from other sources such as road traffic and community noise, making interpretation difficult.

Evaluation of the impact of key noise sources at receptor locations and the benefits of various control options is most easily achieved using a noise model. Noise models use known sound propagation algorithms to determine noise imission at receptor locations. If the sound power of the plant can be determined, the noise impact at receptor locations can be predicted with good accuracy. If the sound power of all individual plant items can be determined, a noise model can predict the cumulative noise imission at receptor locations and identify the most significant noise polluters. These items can then be targeted for noise control mitigation measures.

Determining Plant Noise Emission

A common approach to determining the existing noise emission of an industrial plant can be termed as the "full detail" method, whereby measurements are conducted to determine the sound power of every individual plant item. These are entered into a noise model which is used to predict specific noise levels at receptor locations.

Measurements at receptor locations can then be used to calibrate the noise model, correcting for factors such as source directivity, reflections, absorption, screening and ground effects. When the noise model and environmental measurements have a good correlation, this gives confidence to the accuracy of the model, and allows different noise control scenarios to be evaluated.

Whilst an effective approach, the "full detail" method is time consuming, potentially impacting both survey cost and schedule. This method does however give us two key pieces of information:

- Overall noise emission of the plant; and
- Most significant contributors to plant noise emission.

Knowledge of these is key to developing a noise control strategy. The question that arises is whether these key pieces of information can be determined without obtaining full details of every individual plant item.

In some cases it is possible to estimate the overall noise emission of the plant using environmental measurements and measurements at the plant boundary. This however, doesn't demonstrate the key noise sources. Identifying areas of plant containing the key noise sources, and excluding less significant areas of plant from a detailed study, can give similar results with a significantly reduced survey time.

If the plant is broken down into discrete modules, sound power estimates can be conducted for these. It will then be possible to identify modules which do not make a significant contribution to plant noise emission. These modules can be included in the noise model, but discounted from a more detailed measurement exercise. Figure 1 presents an industrial plant with discrete modules identified.

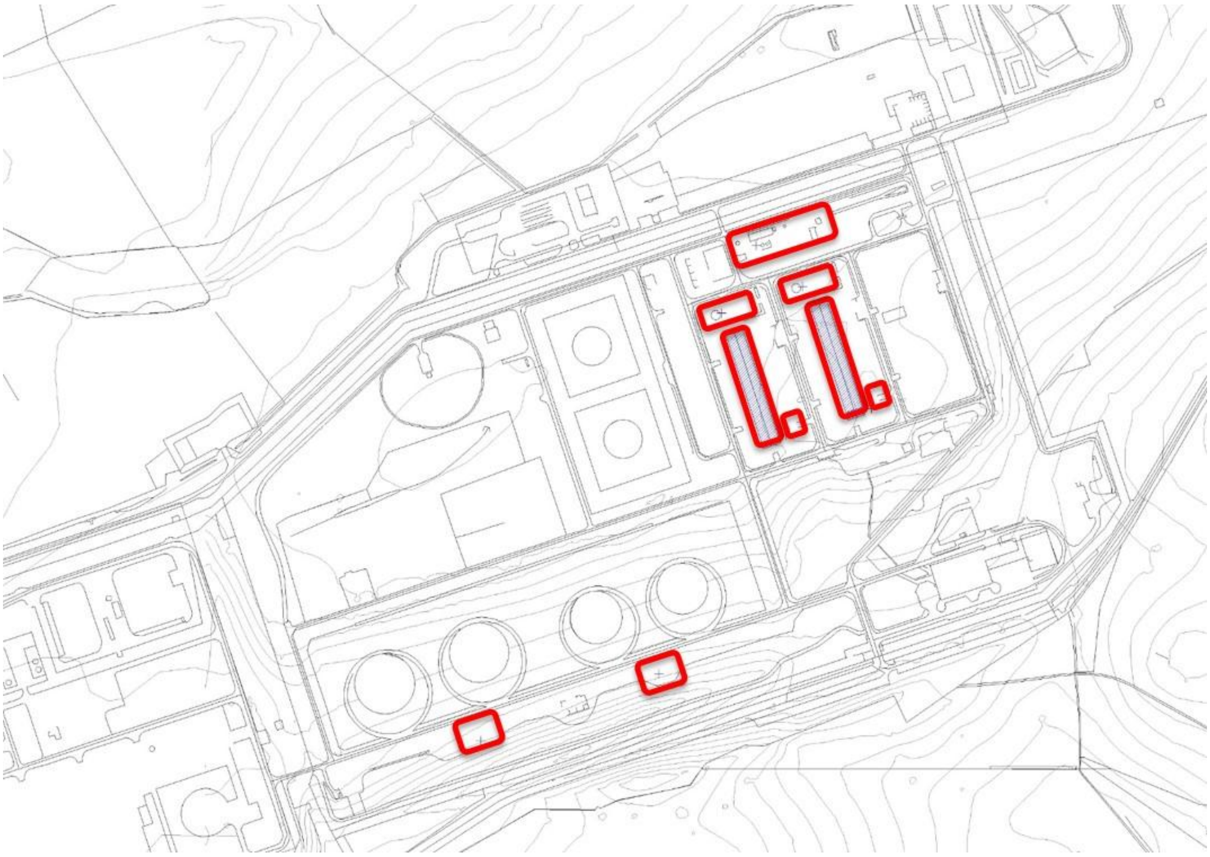

Figure 1 Industrial Plant with Discrete Modules Identified

Modules identified as making a significant contribution to noise emission can be rank ordered and detailed measurements conducted to identify the key plant noise sources. In this way, both the overall plant noise emission and key sources can be identified, potentially with a significant saving in survey time.

Breaking it Down – Module Sound Power Estimation Techniques

If plant modules are spaced far enough apart, distance measurement methods can be used to estimate the sound power of individual modules. A large spacing is required to prevent noise from other modules influencing the measurements. Noise measurements can be conducted at a distance of at least one times the largest source dimension, back from the assumed acoustic centre of the plant. Figure 2 presents a diagram of a distance measurement method.

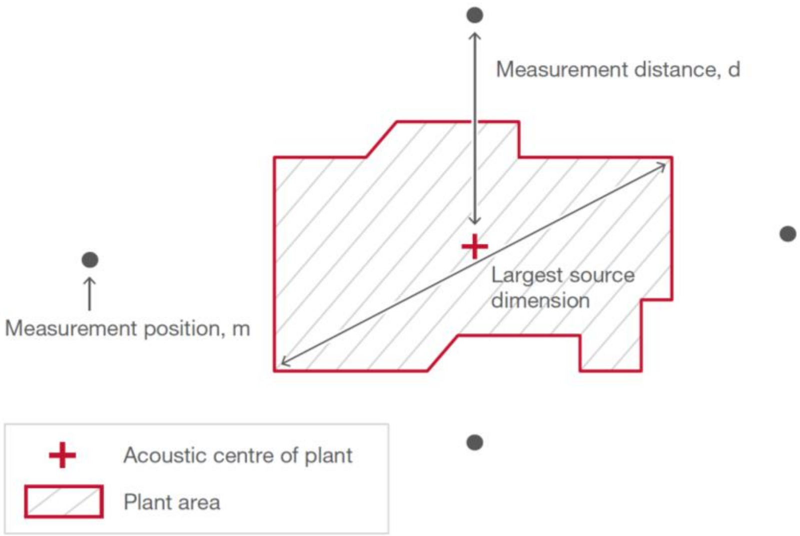

Figure 2 Distance Measurement Method

Normally four directions will suffice, with measurements conducted at a height of at least 4 m above grade. This assumes that other modules will be far enough away not to influence the measurements. Modules on many industrial sites will be placed too close together for such an approach to be valid, so other methods are required.

The method outlined in ISO 8297 (Reference 1) presents a different approach which allows acoustic measurements to occur much closer to a module. This reduces the problem of other nearby modules and noise sources influencing the results. The standard is based on the measurement of sound pressure levels on a closed path surrounding a module with sources combined and treated as a single source at the geometrical centre of the plant.

The standard is applicable to industrial areas where most of the equipment operates outdoors and for which the largest horizontal dimensions of the plant area lie between 16 m and 320 m. It is understood that these limitations are based on the limits of the measurement exercises carried out when developing the method, rather than acoustical or physical constraints. Figure 3 presents measurements on a closed path in line with ISO 8297.

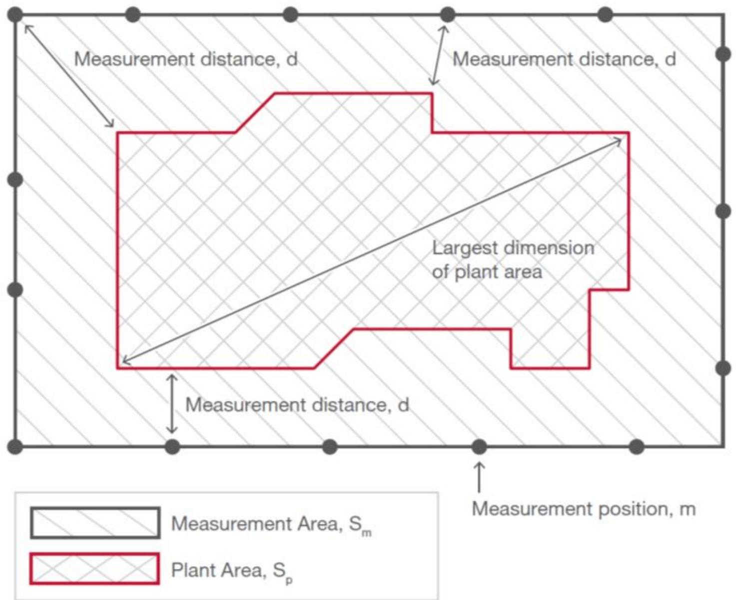

Figure 3 Measurements closer to a module, in line with ISO 8297.

A key assumption of the standard is that the sound power is evenly distributed across the module area, with noise radiation substantially uniform in all directions. Elevated sources of noise (such as air-fin coolers and exhaust stacks) are excluded from the method and need to be measured separately.

The method was initially intended for whole site evaluation, however, reliable results have been obtained when used for measurement of specific modules within industrial sites. Other published work in this field suggests that for larger sites, it can be more effective to determine the sound power of individual modules separately, as proposed in EMMUA 140 (2) and DEFRA (3). An example industrial site noise contour plot with sound power data obtained using this method is shown in Figure 4.

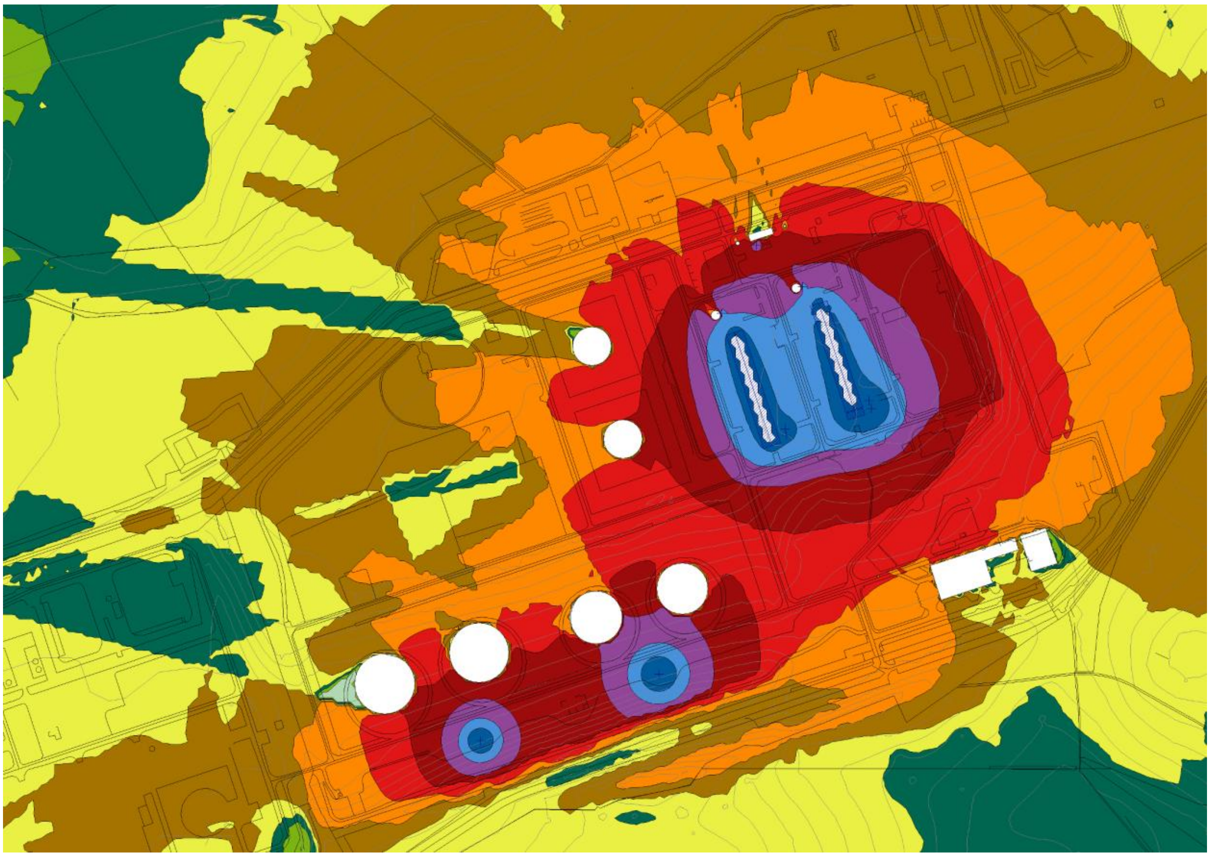

Figure 4 Noise contour plot of an industrial plant, obtained using the ISO 8297 measurement method

The next phase is to rank order the modules making the most significant noise contribution at sensitive receptors. Detailed measurements can then focus on these specific sites.

Detailed Sound Power Determination

Sound pressure is the usual noise measurement technique and is conducted using a sound level meter. A key issue with measuring sound pressure is that extraneous noise is measured in addition to the source under consideration. For detailed measurements in acoustically congested environments, as typically found on petrochemical and process sites, sound pressure analysis can lead to large uncertainties with a tendency to over-estimate source strength.

Two key techniques can be used to determine source sound power in acoustically congested environments. These are:

- Sound intensity; and
- Vibration velocity.

Sound intensity is generally preferred to pressure for determining individual source strengths in acoustically congested environments. Sound intensity is a vector quantity which provides a measure of the magnitude of noise travelling in a given direction. As such, it can reject off axis noise and give a specific measurement of a particular sound source. The main drawback of this is that specialist equipment and expertise is required.

Sources with a high sound power due to a large radiating surface area (such as pipework and ducting) can have relatively low sound intensity levels. In these cases, measuring either sound pressure or the positive intensity vector on an acoustically congested site can be difficult and direct measurement of surface vibration velocity level can give more effective and repeatable results. Vibration velocity is directly proportional to surface sound pressure, therefore, if the radiation efficiency of the surface can be established, then the item's sound power can be determined.

Combining sound power estimation techniques, sound intensity and vibration velocity can give accurate plant sound power determination over a much shorter survey period, positively impacting project schedules and reducing survey cost.

Evaluation and Cost-Benefit Analysis

The sound power data can be entered into a noise model and the specific noise level at receptor locations determined. The most significant noise sources can then be evaluated for potential noise control mitigation. Examples of common noise control options include acoustic pipework insulation, silencers, duct resonator arrays, acoustic enclosures and acoustic louvers. Figures 5 and 6 present example noise output from a noise model. These are noise contour plots of an industrial plant prior to, and following installation of noise control.

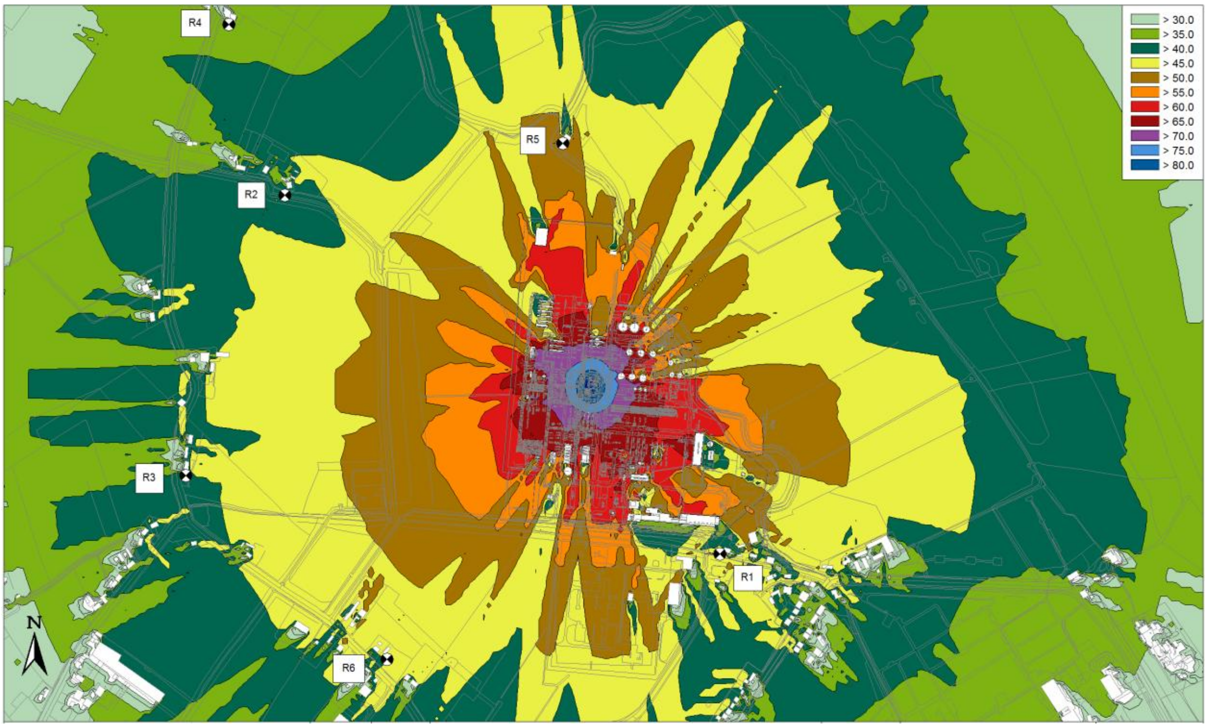

Figure 5 Example noise contour plot of an industrial plant prior to installation of noise control

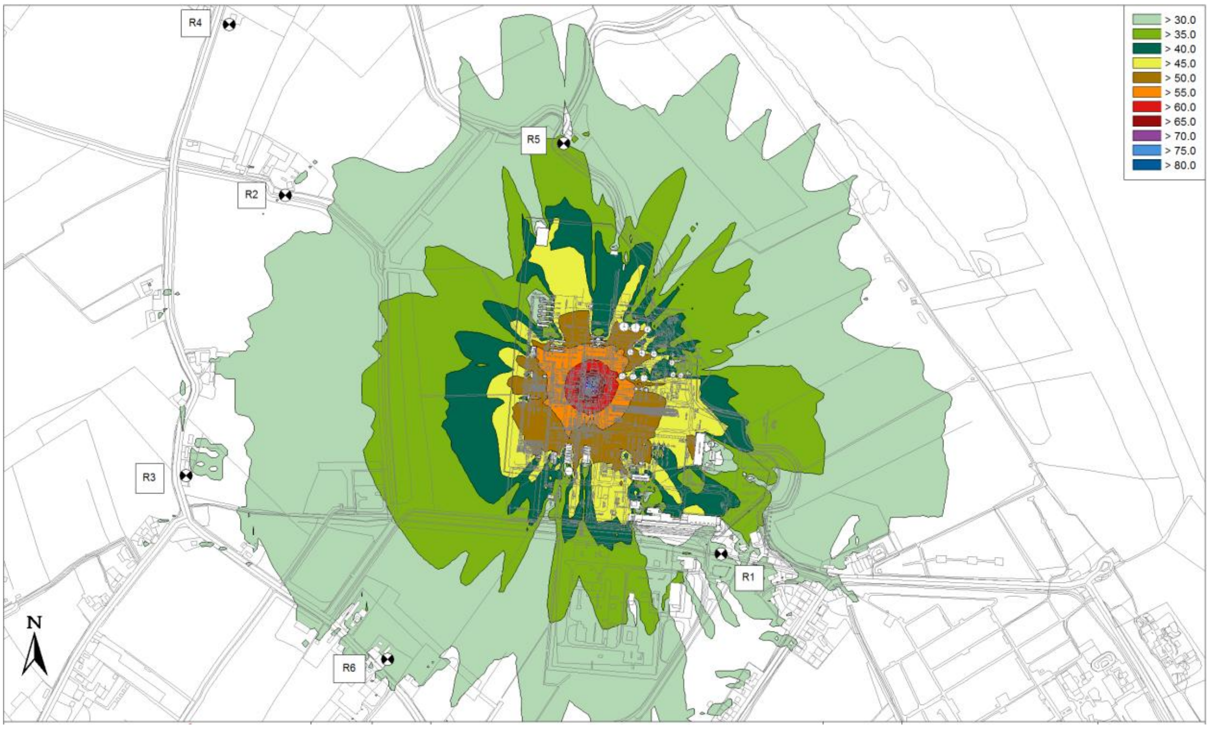

Figure 6 Example noise contour plot of an industrial plant prior following installation of noise control

To produce a cost-benefit analysis, a measure of benefit needs to be determined. Typically this would be the reduction in specific noise level at the closest sensitive receptor, however, for very large sites with multiple receptors, more complex analysis may be appropriate.

The base cost of each noise control option can be acquired from hardware vendors, for input into a cost-benefit analysis. When estimating costs, consideration should be given to materials, installation cost and any ongoing maintenance that may be required for a particular control option.

Once the costs and benefits have been determined a cumulative cost and benefit plot can be produced. An example cumulative cost-benefit analysis plot is presented in Figure 7.

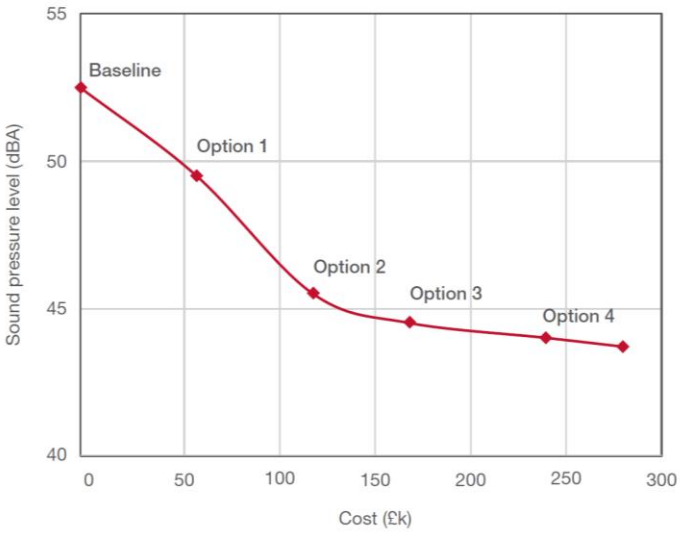

Figure 7 Cumulative cost-benefit analysis plot

The relationship between cost and benefit shown in Figure 7 is typical for such an exercise. There is often a point where additional noise control will increase cost but give diminishing returns in noise reduction. Treating the most significant noise sources first will typically yield the best results, unless costs are an order of magnitude higher than costs for treating less significant sources.

Conclusions

A roadmap for identifying effective noise control mitigation measures at the lowest cost to industry has been presented. It includes considerations for a combined approach to sound power determination and cost-benefit analysis.

When applied intelligently, combining sound power estimation techniques with detailed sound intensity and vibration velocity measurements can offer significant efficiencies in survey cost and schedule.

Conducting a full plant noise survey in this way, allows a full range of noise control options to be evaluated. This enables detailed cost-benefit analysis to be conducted and the most cost-effective combination of noise control mitigation measures to be determined.

This approach will give plant operators confidence to robustly demonstrate the use of best available techniques and meet their obligations under environmental legislation.

Proposed Auralisation Examples

AURALISATION EXAMPLE 1 – Demonstration of how sounds from site modules combine to produce the overall ambient noise environment.

AURALISATION EXAMPLE 2 – Demonstration of how we can determine key sources on a gas compression module.

AURALISATION EXAMPLE 3 – Demonstration of an incomplete noise control solution using an enclosure with exposed pipework.

AURALISATION EXAMPLE 4 – Demonstration of treating pipework and different key sources to achieve a more cost-effective and quieter outcome.

References

(1) International Standards Committee, *ISO 8297:1994, Acoustics -- Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment – Engineering method*, 1994.

(2) Engineering Equipment and Materials User's Association, *EEMUA Publication 140 Noise procedure Specification,* 2014

(3) Department for Environment, Food and Rural Affairs, *Noise Mapping Industrial Sources*, 2003

Notes for the Editor

The main feature of this presentation will be the auralisation examples. These will be audio and video clips to demonstrate to delegates the benefit of various control measures and give context. These will be interactive so clips can be paused in order to develop key themes. I am convinced this will provide a unique and immersive experience for delegates.

The paper below has a certain degree of detail to demonstrate sufficient rigour as required for a technical submission. The presentation will be tailored to match the expected existing knowledge base of the delegates, and will ensure that concepts used in the presentation are suitably explained for non-technical specialists.