NOISE MAPPING OF INDUSTRIAL SITES

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1 INTRODUCTION

There are four main sources of man-made noise, excluding noise in the workplace and noisy neighbours, to which the majority of the population of the country is exposed on a daily basis. These are roads, railways, aircraft and industry, and this is termed environmental, or ambient noise. Noise can have the effect of causing people to feel annoyed, bothered or irritated and can also cause sleep disturbance. In November 2001, the Department for Environment Food and Rural Affairs, Defra, published its consultation paper, entitled Towards a National Ambient Noise Strategy[1], and this gave the intent to map the main sources and areas of environmental noise in England. These maps can then form the basis of strategic plans for noise management.

A separate programme, EU Directive 2002/49/EC[2], which relates to the assessment and management of environmental noise, requires noise mapping to be carried out. It specifies the scope of the mapping, the methodology to be adopted and the outputs to be generated. The four major sources of environmental noise need to be mapped separately. The Directive requires specific noise indicators to be computed which are based on yearly average values. These include an average night-time value, L_{night}, and a composite average value for the whole 24 hour day, L_{den}, with evening and night-time noise levels being weighted more heavily than daytime levels.

To generate a set of noise contours on a map, a measure is required of the strength of each noise source (i.e. sound power level) and an understanding as to how the noise dissipates with increasing distance from the source (i.e. its propagation characteristics). The Directive allows use of existing national computational methods for this purpose or, where none exist, recommends interim methods of computation until such time that the European Commission establishes common procedures. The UK has no “national method” for the calculation of industrial noise and, therefore, the Department for Environment, Food and Rural Affairs (Defra) commissioned Bureau Veritas Acoustic Technology to develop a methodology for this purpose, as part of the first phase of noise mapping, with the emphasis on determining the noise emission values of industrial sites. The methodology developed was to be simple, reproducible and robust. It would also be necessary to ensure that the methodology developed would integrate with national databases on population densities etc and reflect relevant geographical information (GI) data management issues.

This document gives a summary of the major findings of the Bureau Veritas research[3]. The views expressed in this paper are those of the authors and do not necessarily reflect the views of Defra or any other Government department.

2 DOCUMENT REVIEW

The interim computational methods for industrial noise given in the EU Directive are based on four specific standards from the International Standards Organisation (ISO). These are ISO 9613[4], ISO 8297[5], ISO 3744[6] and ISO 3746[7]. Of these, ISO 9613-2 gives a method for calculating the attenuation of sound outdoors including the effects of distance, type of ground, atmospheric composition, screening, and reflections. This standard will be used in the UK’s national method for the calculation of industrial noise.

The extent to which sound is attenuated depends on its frequency content, and low frequency sounds are attenuated less than middle or high frequency sounds. A full analysis would, therefore, consider the attenuation values in octave or third-octave bands. However, ISO 9613-2 also gives a simplified method of calculation using overall dB(A) values. This simplified method has been assessed for its suitability for strategic noise mapping purposes.

The other three standards define methods of determining the sound power level of a noise source or a collection of noise sources. Of these three standards, ISO 8297, which implements the Stüber method[8] for determining sound power, is the most relevant for the purposes of strategic noise mapping, although in this respect it is generally considered to be over prescriptive. Nevertheless, the principles of this standard have been adapted in the Bureau Veritas report to derive one of the two basic methods of noise emission determination.

3 PROJECT CONSULTATION

Consultation was held with Local Authorities, the Environment Agency and other stakeholders in the course of the research project. A questionnaire was sent to all Local Authorities that sought to identify the range, characteristics and perceived significance of industrial noise sources in England. Of the 368 questionnaires sent, there was a 45% response. A total of 43 Local Authorities (26% of the responses) indicated no major industrial noise sources within their area, which implies that the remaining 74% of the Local Authority areas do contain significant sources of industrial noise.

One aspect of industrial noise that differentiates it from transportation system noise is that frequently the sound has one or more distinctive characteristics, potentially giving rise to a higher level of annoyance than might otherwise be expected. This includes tonal noise, such as from a high-speed fan or blower; noise which consists of intermittent louder components (impulsive noise); and high levels of low frequency noise creating a rumbling effect. The results of the questionnaire indicated that some 80% of the industrial sites identified by the Local Authorities in England were considered to have at least one of these characteristics, with 10% exhibiting all three characteristics. The results are summarised in Figure 1, below.

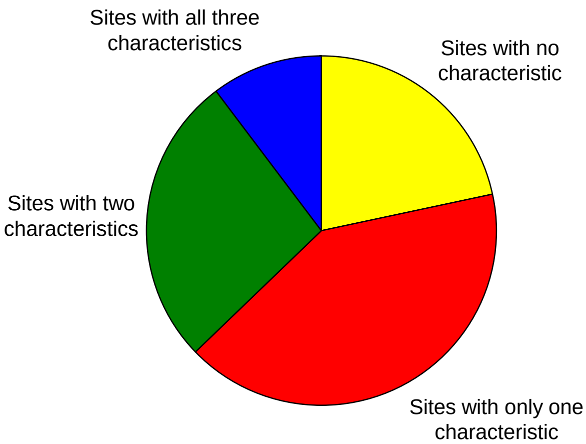

FIGURE 1: Summary of the Percentage of Sites Identified with Various Characteristics

In the consultation with the Environment Agency it was agreed that any simplified method of noise emission determination for strategic noise mapping purposes was unlikely to replace the more detailed noise investigation required for an IPPC (Integrated Pollution Prevention and Control) permit application, which is now required for certain specified industries. For this type of application, which has the goal of leading to increased environmental protection from a range of pollutants including noise, the operator needs to demonstrate they have systematically developed proposals to apply “Best Available Techniques”. The noise data required for this will, in most cases, be more extensive than that for the noise mapping process.

Contact was also made with the government departments with environmental responsibility in Germany, Denmark, France and Holland, to determine any relevant standards or guidelines used in these countries for mapping industrial noise sources. It was concluded that, in general, more focus had been placed on mapping transportation noise rather than industrial noise in these countries.

A detailed review was also undertaken of the pilot noise-mapping project undertaken for the City of Birmingham[9] in 1999. Again, the emphasis in this project was on noise from transportation systems with industrial noise being treated relatively simplistically. Industrial sites included in the project were selected using Birmingham City Council's knowledge of the area, choosing large industrial plants that may have previously or currently had some noise issues associated with them.

Noise measurements were conducted at the majority of these sites. For these, sound power levels were determined by measuring noise levels at a small number of measurement locations, from public access locations. A distance to the centre of the source was assumed and a corresponding sound power level determined. These sound power levels were then placed along factory facades and roofs in the model and it is understood that a degree of "adjustment" was necessary in this procedure to ensure that the computed noise contour values equalled the measured sound pressure level values at the measurement locations.

4 REVIEW OF NATIONAL DATASETS

In order to undertake the industrial noise mapping process and produce the information required, for example, by the EU Directive (including the number of people and dwellings exposed to particular levels of noise), more extensive information will be required, beyond the basic noise data for the industrial site. This includes identification and classification of the industrial sites to be included in the mapping process, topographical information (including building heights), population data and information on the spatial distribution of dwellings. Datasets do exist for a lot of this information although not necessarily at a national level. The 2001 census will be the most important source of information to determine population numbers exposed to particular levels of noise, as the population datasets from this census are now more detailed than for previous censuses. These are contained within a geographic framework of "Output Areas", with some 88% of the Output Areas containing between 110 and 139 households.

5 REVIEW OF SOUND PROPAGATION CONCEPTS INCLUDING EFFECTS OF TEMPERATURE AND RELATIVE HUMIDITY

In deriving noise modelling concepts for industrial sources, it is necessary to have a fundamental understanding as to how sound propagates away from the site. This is in order to be able to quantify potential errors that simplified modelling techniques may introduce. Increasing the distance from the noise source normally results in the level of noise getting quieter, due a combination of the spreading of the sound with distance, ground effects, barriers and atmospheric absorption. The reduction in noise level depends on the frequency of the sound.

Absorption of sound by the molecules of the atmosphere is frequency dependent, with higher frequency sounds more readily absorbed than lower frequency sounds. The factors affecting the extent to which the sound is absorbed are the temperature and the relative humidity of the atmosphere. A review was undertaken to investigate whether it would be necessary to consider daily and seasonal variations in values of temperature and relative humidity to determine yearly averaged noise level as required by the EU Directive. It was concluded that for typical industrial noise, which is biased towards low frequency sounds, this would not be necessary, and a simplified approach could be taken.

A comparison was made of the deviation of atmospheric attenuation values, in dB(A), for a typical atmospheric condition of 10°C and 70% RH, with those for the expected extremes of humidity and temperature that might occur. These values, as shown in Table, are for propagation over a 2 km distance and are for different spectrum shapes.

Spectrum Type:	2 m Receiver Height		4 m Receiver Height	
	Max. Deviation, dB(A)	Mean Deviation, dB(A)	Max. Deviation, dB(A)	Mean Deviation, dB(A)
Flat	-7.8	-1.8	-6.8	-1.7
Typical Industrial	-2.3	-0.7	-2.3	-0.7
Humped	-7.1	-1.5	-6.2	-1.3
Rising	-11.2	-2.5	-9.8	-2.4
Falling	-3.7	-0.9	-3.3	-0.9

TABLE 1: Summary of Results for Deviation for Extremes of Temperature and Relative Humidity

6 DETERMINATION OF SOURCE NOISE LEVEL

To prepare industrial noise maps, a value is required of the noise emission from each site. This is described in terms of its sound power level and is a description of the total amount of sound energy that is radiated from a site.

Three possibilities exist for the determination of the sound power level. These are:

- (i) prediction based on a non-acoustic parameter, for example the number of containers handled per year at a container port;
- (ii) through measurement and calculation;
- (iii) a combination of prediction and measurement/calculation.

In this regard, the results of a study previously carried out in the Rotterdam area of Holland[10] were reviewed. This study included a large number of noise measurements at different types of industrial sites, from which the sound power level of each site was obtained. The study concluded that the sound power level of a particular type of industrial site (e.g. chemical plant, shipyard) could be quantified with a reasonable degree of accuracy based on a typical sound power level for that type of industry and corrected for the area of the site. Table 2 summarises the results of this study.

Type of Industry	SPM, dB(A)/m^2	Standard Deviation, dB	Number of Plants
Chemical plants	70	4	45
Liquids and gas storage	59	4	25
Container terminal	66	1	23
Multi purpose terminal	68	3.5	23
Shipyard	76	5	5
Container repair	70	3	18
Distribution	58	3	20
Waste processing	66	2	14
Construction	70	2	10

TABLE 2: Comparison of Sound Power per Square Metre for Various Types of Industry in Holland

The Bureau Veritas research reviewed this concept for two types of industrial sites in England where overall sound power levels were known (container terminals and gas processing plant). The results of this comparison are shown in Tables 3 and 4, below.

Site	Sound Power Level, dB										Gas Throughput, MMscmd*	L_w per unit throughput
	dBA	31.5	63	125	250	500	1k	2k	4k	8k		
Gas Terminal A	109	117	115	110	107	105	104	102	99	95	4	103
Gas Terminal B	119	124	120	118	116	114	112	112	110	102	28	104
Gas Terminal C	127	132	134	128	123	122	121	121	117	107	26	113
Gas Terminal D	115	130	132	123	114	110	107	106	98	94	26	100
Gas Terminal E	114	133	125	121	115	112	109	104	88	86	30	99

*MMscmd = Million Standard Cubic Metres per Day

TABLE 3: Comparison of Sound Power Level per Unit Throughput for Various UK Gas Terminals

Site	Sound Power, dB(A)	Operational Area, m^2	SPM, dB(A)/m^2
Container Terminal 1	123	240000	69
Container Terminal 2	130	1040000	70
Container Terminal 3	122	700000	64
Standard Deviation			3.5

TABLE 4: Comparison of Sound Power per Square Metre for Container Terminals in UK

It was concluded that, whilst the concept might have some merit, variations in noise emission due to age, location and the type of machinery employed on a particular site precluded its use at present in industrial noise mapping in England. It is, however, possible that such a method might be developed in due time in the light of experience gained using measurement techniques. No other method of determining sound power levels through non-acoustic means were thought viable.

It was concluded that, where noise mapping was to be undertaken in the vicinity of an industrial site, a methodology would be required which was based primarily on noise measurements at each site. An industrial site usually contains a relatively large number of individual noise sources and it was considered that it would be overly complicated, for the purposes of strategic noise mapping, to survey each individual source on a site and enter these into a noise model. Instead, the assumption has been made that noise measurements would be made from publicly accessible positions outside the site boundaries, and the noise emission values of the industrial site determined from these measurements (as an accumulation of individual sources of noise).

An exercise was then undertaken to identify the potential errors if incorrect assumptions were made on the positioning and distribution of the noise sources within the industrial site based on noise measurements taken outside the plant boundary, and the potential errors in the subsequent representation of the noise sources in the noise-mapping computer programme. For this purpose, the noise modelling software package Cadna was used. Noise contours were first of all generated out to a distance of 2 km from the centre of the site, using Cadna, assuming semi-soft ground, with all individual sources of noise on the site being modelled and in the correct positions and distribution patterns. This represented the “true” situation for the purposes of this exercise. However, measurements to determine noise emission values from which the contours would be generated in real life, would usually be made at distances of typically of 100 - 300 m from the site centre, depending on the size of the site. Cadna was therefore also used to determine the “true” noise levels at these measurement positions. These “true” noise levels were then used in a back-calculation to determine the assumed sound power level of the site, based on different assumptions on ground conditions and the location of the acoustic centre of the site. Noise contours were then predicted out to a distance of 2 km (again using Cadna), with relatively simple assumptions on how the site should be modelled. These were then compared with the “true” contours values initially determined to calculate possible errors values. This process is depicted in Figure 2, below.

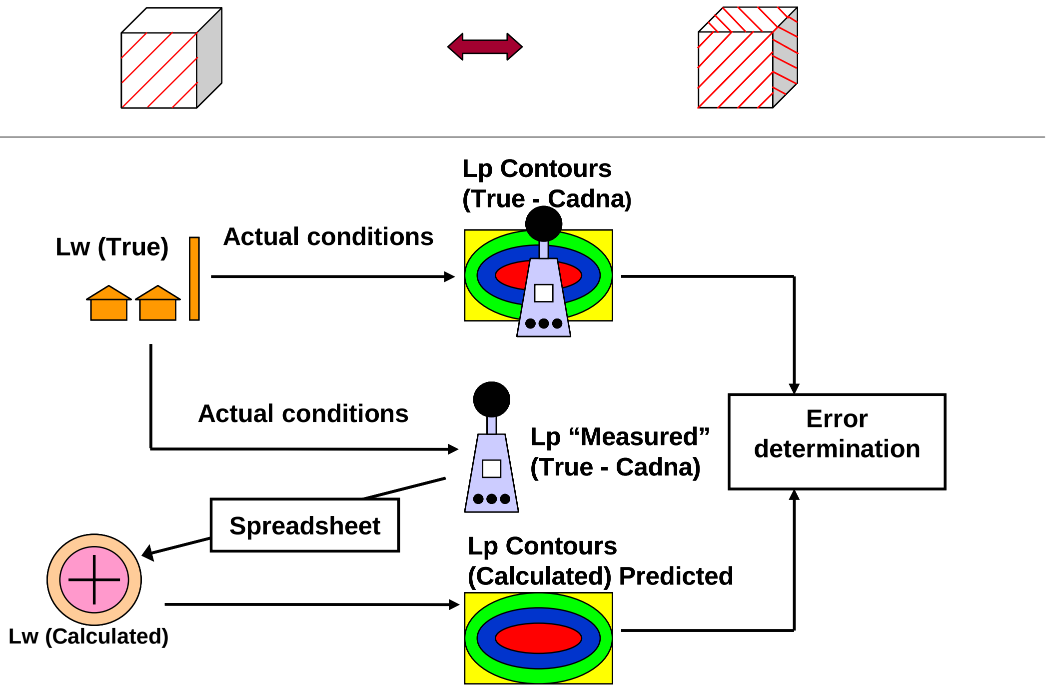

FIGURE 2: Example Modelling Concept

Noise modelling packages allow the representation of a noise source as a "point", "line", or "area" source. Various scenarios were modelled starting from the concept of a simple point source, and increasing the complexity of the model to a hypothetical factory complex with a variety of buildings and different types of noise sources. Intermediate scenarios which were investigated included a model with only one façade of a building radiating noise (directional radiation), a model of a radiating façade of a building surrounded by other buildings in order to investigate the effects of in-plant reflections, a point source on the roof of a building to investigate screening effects by the edge of the roof and the noise radiation from a stack.

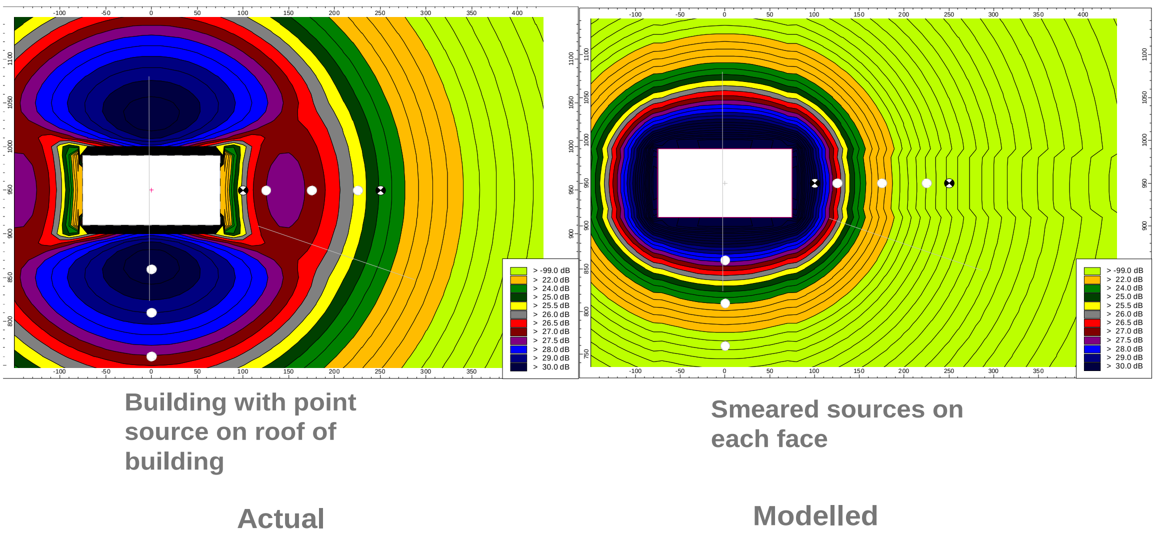

FIGURE 3: Example Noise Map Outputs for Modelling Scenarios

Measure - source distance, m (to side of building)	Back calc Lw using 500 Hz	Measure-ment points	Error L_{pA} Calc - L_{pA} True at distances from centre, m, (assume 50% "soft" ground), receiver height 4m				
			100	250	500	1000	2000
50	500	1 short	7.9	-2.1	-2	-1.2	-0.9
50	500	1 long	2.7	-7.4	-7.3	-6.5	-6.2
50	500	Average	**6.0**	**-3.9**	**-3.9**	**-3.1**	**-2.8**
50	Full	1 short	1.9	-8.4	-8.4	-7.5	-6.6
50	Full	1 long	2.7	-7.6	-7.6	-6.7	-5.9
50	Full	Average	**2.3**	**-7.9**	**-7.9**	**-7.1**	**-6.2**
100	500	1 short	5.8	-4.2	-4.1	-3.3	-3
100	500	1 long	6.2	-3.8	-3.7	-2.9	-2.6
100	500	Average	**6**	**-4**	**-3.9**	**-3.1**	**-2.8**
100	Full	1 short	5.7	-4.7	-4.8	-4.1	-3.5
100	Full	1 long	6.2	-4.2	-4.3	-3.7	-3.1
100	Full	Average	**5.9**	**-4.4**	**-4.5**	**-3.9**	**-3.3**
150	500	1 short	7.4	-2.6	-2.5	-1.7	-1.4
150	500	1 long	7.4	-2.6	-2.5	-1.7	-1.4
150	500	Average	**7.4**	**-2.6**	**-2.5**	**-1.7**	**-1.4**
150	Full	1 short	7.7	-2.8	-3.1	-2.5	-2.2
150	Full	1 long	7.7	-2.8	-3.1	-2.5	-2.2
150	Full	Average	**7.7**	**-2.8**	**-3.1**	**-2.5**	**-2.2**

TABLE 5: Example Errors Derived From Cadna Modelling

General conclusions are that large errors can be encountered if information is not known about how directional the noise from the site is. This error can be reduced, not surprisingly, by increasing the number of measurement locations around the site. Directivity effects may be reduced by in-plant reflections in real industrial sites. Measurements at greater distances from the noise source generally result in lower errors in the produced noise contour values, but in real life account will need to be taken of residual noise (i.e. noise not due to the industrial site), and this will limit the distances at which measurements can be taken. Increasing the measurement height also has benefits in reducing errors. The concept of breaking down a physically large noise source into a series of point sources was also investigated, and corrections factors derived to improve accuracy of modelling.

Cadna was further used with a hypothetical factory complex model to determine the accuracy of noise contour predictions based on the ISO 8297 method of sound power level determination, with different spatial representations of the calculated sound power level. In this case, it was found that using this method of sound power level determination and representing the noise from the industrial complex as a two dimensional area source (i.e. smearing the sound energy over the site area) gave slightly better accuracy in predicted noise levels nearest to the site, as compared to a point source representation. For an alternative method of sound power level determination based on more distant "measurements" there was very little difference in accuracy in representing the site as an area or a point source at distances greater than 1 km from the site.

7 SITE INVESTIGATIONS

Noise measurements were taken at two real industrial sites to test the logic and robustness of the determination of sound power levels and subsequent contour predictions, to further determine the potential errors inherent in the modelling methods and to appreciate the practical difficulties of undertaking noise measurements for the purposes of strategic noise mapping. The first site was a large factory unit in a mainly residential area and the second site was an open-air industrial site in a rural area with many individual sources of noise within the plant area. The site location and measurement positions used for the factory site are shown in Figure 4.

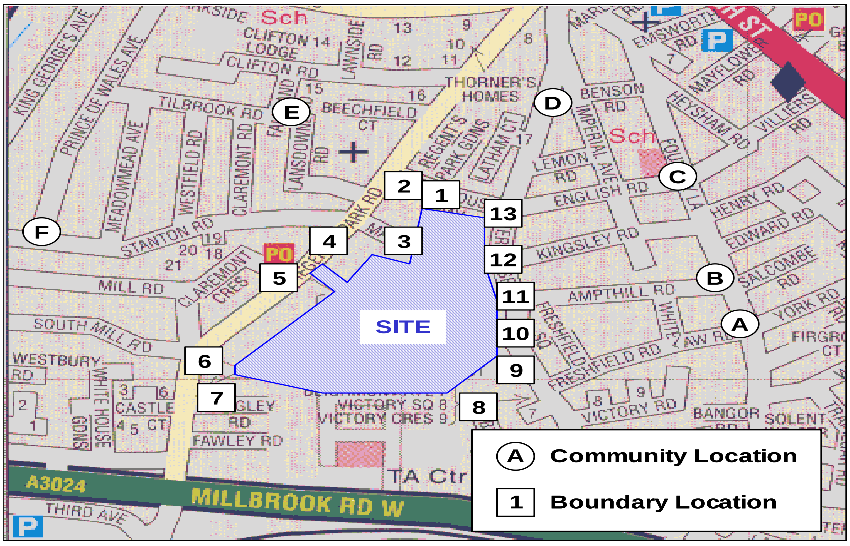

FIGURE 4: Noise Measurement Positions for Factory Unit Tests

The experience at the factory site indicated that, in an urban environment and even when the survey was undertaken in the early hours of the morning, measurements would often need to be made at the site boundary to determine site sound power levels for the purpose of generating noise contours (rather than at more distant locations). This was on account of background noise due to road traffic etc. that can persist throughout the night. The results of the survey are summarised in Tables 6 and 7, below.

Calculation Method	Sound Power level, dB(A)
Octave Band	97.1
Single Band	97.7

TABLE 6: Comparison of Sound Power Level Determination for Full Octave and Single Band Calculations for Factory Unit Tests

Method	Sound Pressure Level, dB(A)					
	A	B	C	D	E	F
Octave Band	27.0	30.7	29.3	31.0	29.4	26.1
Single Band	27.9	31.7	30.3	32.0	30.7	27.2
Actual Measured L_p	34.6	33.8	35.0	32.3	35.3	38.5
Estimated Residual Level	30.0	30.0	30.0	30.0	30.0	30.0
Corrected Measured Level	32.8	31.5	33.3	28.4	33.8	37.8

TABLE 7: Comparison of Calculated Sound Pressure Levels With Measured Values for Factory Unit Tests

The measurements at the open-air industrial site were not affected by background noise and these were used in two ways to determine the sound power level of the site (i) from site boundary noise measurements, and (ii) from more distant noise measurements. The measurement positions used are shown in Figure 5, below.

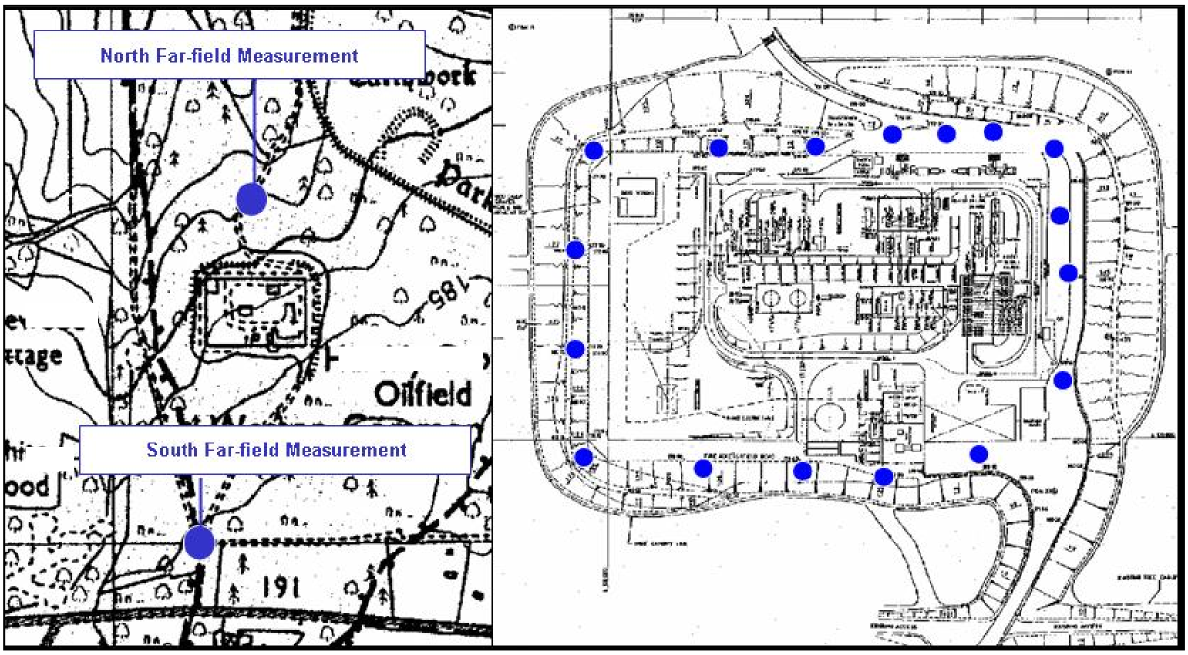

FIGURE 5: Measurement Positions – Open Site Tests

The results from the tests were compared with the results of a previous investigation that had derived the sound power levels of individual noise sources on the site and which were then summated to give the total sound power level of the site. The results of this exercise are presented in Tables 8 and 9.

Calculation Method	Sound Power level, dB(A)	
	Octave Band	Single Band
Stüber Method (based on ISO 8297)	105.4	104.1
Hemispherical Calculation (From North)	105.3	105.4
Hemispherical Calculation (From South)	105.8	105.8
Small Source Method (Intensity)	*103.9*	-

TABLE 8: Comparison of Calculated Sound Power Level for Different Methods of Determination – Open Site Tests

Method	Sound Pressure Level, dB(A)	
	260 m North	320 m South
Stüber (based on ISO 8297)	42.4	41.5
Hemisphere North	43.6	42.7
Hemisphere South	43.7	42.8
Actual Measured SPL	*41.5*	*39.9*

TABLE 9: Comparison of Calculated Sound Pressure Levels with Measured Values Using Single Band Calculations - Open Site Tests

It was concluded that there is good correlation between the methods for sound power level determination.

8 RECOMMENDED METHODOLOGY FOR SOURCE NOISE LEVEL DETERMINATION

Any method for representing industrial noise sources for the purposes of noise mapping will need to be a compromise between obtaining an adequate level of detail and accuracy and making the method suitably simple in terms of use and output. The proposed methodology is based on the measurement of noise levels in the vicinity of, but not actually on, the industrial premises. This is to ensure easy access to the measurement locations, as well as providing one or more positions outside the industrial site that can be used to calibrate the accuracy of the computed noise contour values. As the number and location of suitable access points for noise measurements will vary from site to site, a flexible approach has been proposed.

Once the sound power level of the industrial site has been determined, then its numerical value, and the assumed location of the noise source(s) and their spatial distribution, needs to be assigned to the computer model that is to be used to generate the noise contours, in a way which minimises potential errors. Some sites will radiate more noise in one direction than another, and this directional effect needs to be identified, where possible, from the measurements. An industrial site may not have an even distribution of noise sources across the site, and its “acoustic centre” may not necessarily be the same as its geometric centre. The determination of the location of the acoustic centre of an industrial site will help to minimise potential errors in the subsequent noise mapping process.

The noise contours will be generated by the particular noise modelling software package to be used, based on the algorithms for sound propagation given in ISO 9613-2. A full understanding of how the software package interprets the detailed algorithms in the standard is especially important with respect to the simplified method of sound propagation calculations over acoustically “soft” versus acoustically “hard” ground.

9 RECOMMENDED MEASUREMENT METHODS

The proposed measurement methods given in the Bureau Veritas report for determining noise emission levels of industrial sites are intended solely for the purposes of industrial noise mapping for strategic purposes. For planning and permitting requirements relating to environmental noise, it will almost always be the case that a much greater level of detail will be required than can be obtained from these simplified methods.

It will be necessary to plan the measurement survey to take into account plant operating conditions, including daily or seasonal variations, such that the appropriate long-term average noise parameters, as required by the Directive, can be computed. Although the proposed methods have assumed that all noise measurements will be made from publicly accessible locations, knowledge about the industrial site will be required to understand its operating hours and any variation in operating conditions that might influence its noise emission. This will most likely require contact with the industrial site to gather the relevant information, assuming that an external agency, and not the industry concerned, is undertaking the initial strategic noise mapping exercise.

Measurements will need to be taken under appropriate weather conditions, as wind speed and direction, in particular, will have an influence on the measured noise levels, depending on the distance of the measurements from the site. Noise measurements will also need to be conducted when the interference from other sources of noise (e.g. roads, railways, aircraft etc) is at a minimum. For sites that operate in a similar manner 24 hours per day, the most appropriate time for the measurements will normally be late at night or early morning. Where levels of background noise are found to be interfering with the measurements associated with the industrial site under investigation, then correction factors will need to be applied. The equipment used to undertake the noise measurements will need to be fit for purpose and kept fully calibrated.

Two principal measurement methods have been proposed for the determination of noise emission values from industrial sites. These are the close-proximity (or site boundary) method and the distant measurement method. In principal, the distant measurement method is preferred, but its use may be precluded due to obstruction by buildings between the required measurement locations and the site, or the presence of high background noise levels from other sources of noise.

For both measurement methods, general guidance is given in the Bureau Veritas report on preferred measurement locations including the height of the microphone. Measurement positions should only be used where the noise from the industrial site is audibly dominant and care needs to be taken if there are nearby reflecting surfaces, as these could distort the results. For the close proximity method, the method of calculating the sound power level requires an estimation of the area of the industrial site from which the noise radiates, the area contained within the contour prescribed by the measurement locations, and the average height of the noise sources. From this, an area value is calculated which is used in the sound power level derivation. Correction factors for measurement proximity effects and air absorption are also determined through calculation. Guidance, in the two methods, is given on which noise parameters to measure, and how the effects of extraneous intermittent noise may be minimised by the appropriate choice of parameter.

Although an industrial site may be physically large, it is possible to treat it as a point source for the purposes of sound power level determination if the noise measurements can be made reliably at suitable far distances from the centre of the site. This distant measurement method is suitable for measuring industrial noise sources in open areas where there is a direct line of sight to the site in several directions and for sites where these more distant measurements can reliably be made. The method is based on the concept of the sound energy expanding on a hemispherical wave-front from the centre of the source, with corrections being applied for the type of ground over which the sound is propagating and the direct absorption of sound by the atmosphere. Where possible, at least four measurements should be taken around the site at 90 degrees to each other, with additional measurements taken at even greater distances from the site in each direction. These will help to define whether noise from the site is directional in nature. Also the differences in the values obtained from the more distant measurements as compared with those at the closer locations, may be used to calculate the exact acoustic centre of the industrial site. This then reduces subsequent errors in the noise mapping process. Care needs to be taken, however, to avoid meteorological effects skewing the results, particularly upwind of the site, and where any doubt exists, downwind measurements should be used as the primary indicators to calculate the location of the acoustic centre of the site and its sound power level.

10 APPLICATION OF DATA

It was not in the scope of the Bureau Veritas project to comment in any detail on the ISO 9613-2 sound propagation model or on its suitability for industrial noise mapping. It was of relevance, however, to consider the way in which the sound power level for a particular site should be distributed in a noise modelling software package that uses ISO 9613-2. In principle, it is recommended that for any industrial site, the sound power level be distributed in a manner as similar as possible to the real situation. Therefore, for a large factory building, where there is no obvious individual dominant source of noise, the sound power should be distributed over the facades and roof of the building in the noise model. For a large open industrial site with a multitude of individual noise sources, the site should be represented as a 2 dimensional "area" source in the noise model. Values of directivity also need to be assigned to the noise source, wherever practicable.

For industrial sites that do not operate continuously, or have varying noise emission on a seasonal or daily basis, corrections need to be applied to obtain yearly average values of the sound power levels. Mathematically, this is a relatively simple procedure as long as details are known of the operating periods of the plant and the resultant noise levels under different operating conditions. Local knowledge will be necessary for this purpose, with assistance most probably being sought from the industrial site concerned. In some situations it may be necessary to undertake noise measurements on more than one occasion to obtain the required yearly average values.

11 CONCLUSIONS

It was concluded that the simplified methodology proposed would allow consistent and reasonably accurate representation of industrial noise sources for strategic noise mapping purposes that will provide the necessary firm basis for future assessment in relation to the requirements of the EU Directive and the National Ambient Noise Strategy.

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