

A Practical Evaluation of Objective Noise Criteria used for the Assessment of Disturbance due to Entertainment Music

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Abstract

Existing methods of objectively assessing complaints regarding noise disturbance are predominantly based on A-weighted noise measurements. However, A-weighted measurements are inappropriate where the noise contains a significant proportion of energy at lower frequencies.

Noise complaints received by environmental health service providers have increased dramatically over the past 10 to 15 years. Noise arising from entertainment premises is now a common cause of disturbance to nearby residents. A-weighted measures are inappropriate for the assessment of this type of noise due to the large, low-frequency, bass-beat element contained in modern music.

The study on which this paper is based sought to evaluate the effectiveness of a number of selected noise criteria used for the assessment of disturbance caused by music from entertainment premises. The effectiveness of each was determined by how well the objective assessment result concurred with the investigating officer's subjective assessment of the noise. Additionally, the strength of the relationship between the objective and subjective measures was determined by statistical analysis.

It was found that the German criterion DIN 45680 (Deutsches Institut für Normung, 1997) performed best as a predictor of the subjective assessment of nuisance, but that the 1/3 octave bandwidth analysis of the criterion contained with the Institute of Acoustics – Good Practice Guide on the control of noise from Pubs and Clubs - Draft Annex 2 (Institute of Acoustics, 2002), resulted in the strongest statistical relationship.

Government has accepted the need for a scientifically robust criterion for the assessment of disturbance caused by entertainment music. The results of the study on which this paper is based would suggest that a 1/3 octave bandwidth analysis is essential as part of any new assessment criterion and that the German criterion DIN 45680 should be considered in further research toward the development of such a criterion.

Key words: Bass beat, Entertainment music, Low-frequency noise, Noise criteria, Noise disturbance.

Introduction

Over the last 10 to 15 years, environmental health services within local authorities have observed a sustained increase in the number of complaints received about noise. In many cases noise disturbance is now the most common reason why a member of the public has the need to make contact with their local authority (DEFRA and CIEH, 2003).

For many local authorities, weekends result in numerous complaints regarding noise from pubs and clubs. Increasingly powerful music systems, the desire for late night entertainment and the increase in leisure time have all contributed to a situation where many residents have their sleep disturbed by music being played in nearby entertainment premises.

Music consists of energy at a wide range of frequencies. Modern musical styles contain a relatively large amount of energy at low-frequency, which provides a rhythm to the music; this is sometimes referred to as bass beat.

Persons who are being disturbed by a bass beat will often say that they can both hear and feel the noise 'throbbing'. It has been suggested that the feeling associated with bass beat results from the low-frequency noise causing resonance within the chest cavity of the exposed person. Therefore, the effects of low-frequency noise differ from broadband noise and research has shown that noise containing a large amount energy at lower frequency is more annoying than the same sound pressure level without the low-frequency element (Perrson *et al*, 1990).

When investigating complaints relating to entertainment music, it is common practice for the local authority officer to gauge the level of disturbance by both subjective assessment and objective noise measurement. However, no objective noise criterion has ever been proven to be sufficiently

scientifically robust to assist in the assessment of disturbance which is specifically due to music from entertainment premises.

In the absence of a specific objective criterion, the guideline values contained in the Guidelines for Community Noise (WHO, 2002) are frequently used. These criteria are predominantly based on A-weighted, equivalent continuous measurements. A-weighting is a decibel correction applied to a sound to represent how the human response varies with frequency. It applies a large negative correction at the lower end of the frequency spectrum.

A-weighted noise levels have been shown to under-represent the annoyance caused by low-frequency noise (Perrson *et al*, 1990). Therefore, A-weighted measures should not be used for the assessment of low-frequency bass beat; indeed the WHO document itself advises that A-weighted measures are inappropriate when prominent low-frequency components are present.

Despite this advice, a 2002 survey of Chief Environmental Health Officers in UK local authorities indicated that A-weighted levels were still being frequently used by Environmental Health Practitioners when investigating complaints of low-frequency noise disturbance (Guest, 2003).

A further problem arises because the equivalent continuous sound pressure measurement is a single figure expression of a wide range of audible frequencies. As a result, the influence of an elevated sound pressure level at one specific low frequency may be under-represented in the overall single figure result. Perrson *et al* (2001) support this point by suggesting that the human annoyance response is directly related to the sound pressure levels of the dominant low-frequencies rather than a broad spectrum measure.

It has become widely accepted that a more representative objective criterion is needed to assist in the determination of whether the noise due to entertainment music is giving rise to a statutory nuisance or not.

The study on which this paper is based sought to evaluate the effectiveness of various objective noise criteria when they are used to assess the disturbance caused by music emanating from entertainment premises.

The need for a new assessment criterion

The presence of a nuisance due to noise affecting residential premises is commonly assessed by comparing the equivalent continuous, A-weighted, sound pressure level to the measured background noise level (in the absence of the noise) and to

some objective criterion such as the WHO guideline values.

However, assessments of entertainment music conducted in this manner tend to under-estimate the disturbing effect of the noise and therefore the likelihood that a nuisance exists. The problem is exacerbated by the fact that it is the low-frequency energy in the music that is more transmissible over distance and through building structures. Furthermore, as low-frequency noise tends not to be present in the background noise environment, the introduction of a low-frequency bass-beat will be more noticeable to nearby residents, particularly late at night.

In a research report on low-frequency noise DEFRA acknowledged the difficulties experienced by environmental health practitioners in measuring and assessing the impact of noise of this type (DEFRA, 2001). Following on from the research report DEFRA published a review of published research into low-frequency noise and its effects (DEFRA, 2003a). Referring in general terms to the deficiencies in the assessment criteria that were commonly used, the review stated, "A not uncommon occurrence is that there is clearly a low frequency noise present at a complaint location, but existing U.K. assessment methods are not able to determine its nuisance value, leading to the conclusion of 'Not a Statutory Nuisance,'" (DEFRA, 2003a, pg 7). The review acknowledges that further research into the development of appropriate criteria is required.

The UK Government suggests areas of environmental research that it will consider supporting in the annual DEFRA Environmental Protection Research Newsletters. The 2003-2004 edition suggests that research is required into suitable low-frequency noise assessment criteria (DEFRA, 2003b). Furthermore, the 2004-2005 edition (DEFRA, 2004) details a specific research project to assess the validity of the criteria contained in the Institute of Acoustics – Good Practice Guide on the control of noise from Pubs and Clubs – Draft Annex 2.

Criteria selected for study

The problems in assessing low-frequency noise are not new and have been known to acoustics practitioners for many years. Numerous assessment criteria have been proposed, some in relation to specific applications, others more general; yet none has become widely accepted for use in assessing noise from entertainment music.

One common method of objective assessment currently used by Environmental Health Practitioners considers that a noise nuisance is present where the measured noise level exceeds the WHO guideline value of LAeq (equivalent continuous sound pressure level) 30dB within a dwelling at night and is also at least 10dB in excess of the measured L90 (90% percentile of the equivalent continuous sound

pressure level) background noise level.

In the study on which this paper is based, an extensive literature search was conducted to identify noise criteria (in addition to the WHO guideline value) which could potentially be applied to the assessment of disturbance due to entertainment music. In total twelve 'alternative' methods were identified and the five most relevant and practical were selected for study. A number of criteria such as those in the Noise Act 1996 were excluded because existing studies had shown that they performed poorly as a predictor of annoyance when the noise contained significant low frequency elements (Morrissey, 2003). Others such as the Dutch method contained in 'NSG - Richtlin Laagfrequent Geluid, 1999' (cited in DEFRA, 2003a) were excluded as they sought to assess whether the noise was audible or not rather than the annoyance caused.

The criteria selected for further study were:

Institute of Acoustics - Good Practice Guide on the control of noise from Pubs and Clubs - Draft Annex 2 (Institute of Acoustics, 2002).

Of the selected criteria, this was the only one that specifically applied to entertainment music. This document contained a range of different criteria that became more stringent as the frequency and duration of the entertainment music increased. The criterion in relation to entertainment music that continues beyond 23:00hrs has two parts. If the limit values in each of the parts are exceeded then the noise is considered to be a nuisance. The first part of the criterion states that the LAeq (music on) should not exceed the L90 (music absent). The second part states that the L10 (10% percentile equivalent continuous sound pressure level) with the music on should not exceed the L90 with the music absent in any 1/3 octave bandwidth between 40Hz and 160Hz, (I.O.A., 2002). The objective criteria were subsequently withdrawn from the draft and are not contained in the final version of the document (I.O.A., 2003).

The loading of A-weighted measurements to take account of low-frequency energy.

This method was the authors' adaptation of a study reported by Kjellberg (1997) which utilised the A-weighting and C-weighting networks available on most sound level meters. The C-weighting network does not apply as large a negative correction at low frequency as the A-weighting network, therefore C-weighted measures take more account of the low-frequency energy in a noise. In this criterion a loading of 6dB is arithmetically added to the measured A-weighted level where the difference between the A and C-weighted levels exceeds 15dB. The resulting rating level was deemed to represent a noise nuisance if it was 10dB or more in excess of the measured background noise level.

Danish criterion - Low frequency A-weighted noise level.

This criterion was taken from the Danish national guidelines contained in Information No.9/1997 for the Danish Environmental Protection Agency reported

on by Jakobsen (2001). The criterion uses a logarithmic summation of the 1/3 octave bandwidth measurements between 10 and 160Hz to give a parameter known as the Low-frequency A-weighted Level (LpA,LF). A limit value of 15dB (impulsive / rhythmic) is set for inside dwellings at night.

German criterion - DIN 45680 (Deutsches Institut für Normung, 1997).

The German criterion for non-tonal noise uses a logarithmic summation of only those measured 1/3 octave bandwidths between 10Hz and 80Hz which exceed the specified threshold of hearing. A limit value of 25dB is applied for night-time noise. The criterion is based upon studies of low-frequency noise annoyance from industry and its use in UK nuisance investigations has been reported on by Rushforth *et al* (2002).

Polish criterion - Recommendation No.358/98 of the Building Research Institute (Poland).

This criterion has been reported on by Mirowska (2001). There are two elements in the assessment: first the measured 1/3 octave levels must exceed a reference curve representing 'comfortable' acoustic conditions. Second, the measured levels must exceed the measured background noise by more than 6dB. The noise is considered to be annoying if both elements are met in any one of the 1/3 octave bandwidths between 10 and 250Hz.

Methodology

The study on which this paper is based sought to evaluate the effectiveness of a number of objective noise criteria when used to assess the disturbance caused by music from entertainment premises. It was conducted within the context of statutory noise nuisance investigations carried out by Environmental Health Practitioners in the UK.

Typically, these investigations will consist of a subjective assessment of the disturbance caused by the noise supported by an objective noise measurement and assessment. The effectiveness of each of the assessment criteria was determined from how frequently the objective assessment concurred with the subjective assessment and from a correlation and regression analysis of the objective and subjective values.

Fieldwork was conducted over a seven-month period and each of the 28 samples obtained related to an actual complaint of noise disturbance due to entertainment music.

One five-minute noise measurement was applied to each of the assessment criteria. Some of the criteria specified different measurement techniques. In order to ensure that the same noise was being assessed by each criterion, it was necessary to adopt a single measurement procedure for obtaining data. It was decided to follow the specified procedure in the Institute of Acoustics - Good Practice Guide on the

Table 1.0: Subjective assessment scale.

Subjective level 1 = entertainment music noise is very faint and barely audible; concentration is required to distinguish the entertainment music noise over the background noise; the absence of the entertainment music noise is more noticeable when it stops than its presence when it is on.

Subjective level 2 = entertainment music noise is distinguishable but at a low level; specific lyrics are not identifiable; entertainment music noise would be masked by normal speech or television volume.

Subjective level 3 = entertainment music noise is clear and distinct; lyrics may be identifiable; audible over normal speech or television volume; sleep would prove difficult in this climate; noise would constitute a statutory nuisance if regular and prolonged.

Subjective level 4 = entertainment music noise is dominant over all other noise; sleep would prove impossible; individual incident would constitute a statutory nuisance if prolonged.

Subjective level 5 = entertainment music noise pervades entire premises where measurement is taking place; sensation of vibration may be felt; entertainment music noise audible throughout general external area.

control of noise from Pubs and Clubs – Draft Annex 2 (IOA, 2002), as this was the only criterion that directly related to entertainment music. It was noted that the Danish criterion specified that measurements were carried out at three positions to account for the spatial variation within a room. In order to minimise the effect of room nodes, measurements were not taken in the corners of the room and reflections were avoided where possible.

The assessments were all conducted within the bedrooms of affected residential premises. In common with established monitoring practice, the doors of the bedroom were closed during measurement. The windows were either open for normal ventilation or closed dependant upon the occupier's preference when using the room. Background measurements were conducted in the same location at a representative time when the music was absent.

Objective noise measurements were taken using a calibrated and field-verified sound level meter with real-time 1/3 octave bandwidth analysis capabilities. Measurements were taken over a five-minute averaging period typical for night-time noise assessments.

The subjective assessment was conducted simultaneously during the five-minute measurement period. The subjective level was quantified using a five-point scale ranging from level one, where the music was faint and barely audible, to level five where the music could be heard over a wide area. Subjective level three, where the music was clear and distinct, the lyrics may have been identifiable and sleep would have proven difficult, was deemed to represent a noise nuisance. Table 1.0 shows the subjective assessment scale used.

The subjective level was directly related to the effect that the noise might be having upon the occupiers of the affected residential premises. This is the basis of the assessment of statutory noise nuisance as the noise must be more than just present – it must result in a material interference with the occupier's use and enjoyment of their premises. A five-point scale was chosen as it was considered that there were insufficient stages of human annoyance response to allow a larger range.

All persons taking part in the study were professional officers with experience of noise assessment. To further aid consistency, all were given specific training in the objective measurement and subjective assessment methods and guidance documents were provided detailing the measurement method and subjective assessment scale.

The majority of entertainment music complaints in the study related to night-clubs, pubs and social clubs; additionally a number of complaints related to noise from an indoor dance-music concert.

None of the residential premises in which assessments were conducted structurally adjoined the entertainment premises. The distance between the residential premises and the entertainment premises ranged from 1m to 285m. The majority of complaints related to entertainment premises over 100m away.

Discussion of results

Table 2.0 shows the results of the statistical analysis between the subjective and objective levels and the percentage concurrence with the subjective assessment.

It was found that the existing method, based on WHO guideline values and an increase of 10dB or more on the background noise, concurred with the subjective assessment of nuisance in 57% of the sample. The regression and correlation analysis showed a moderate to weak relationship between the objective and subjective levels. Regression analysis of the sample indicated that an increase of 16dB on the background level would have better represented the level at or above which a noise nuisance existed.

The first element of the IOA Good Practice Guide on the control of noise from Pubs and Clubs – Draft

Table 2.0: Comparison of the Effectiveness of each of the Objective Criteria in the Assessment of Subjective Noise Nuisance.

| Assessment Criterion | Correlation Coefficient | Degree of Explanation | Limit Value Specified | Limit Value From Regression | Percentage Concurrence with Subjective |
|-------------------------|-------------------------|-----------------------|-----------------------|-----------------------------|--|
| WHO and background | 0.54 | 0.29 | +10dB | +16dB | 57% |
| Pubs & Clubs (1st part) | 0.54 | 0.29 | +1dB | +16dB | 29% |
| Pubs & Clubs (2nd part) | 0.74 | 0.54 | +1dB | +32dB | 29% |
| Loaded A-weighted | 0.61 | 0.37 | +10dB | +20dB | 43% |
| German | 0.69 | 0.48 | 25dB | 26dB | 82% |
| Danish | 0.66 | 0.43 | 15dB | 64dB | 29% |
| Polish (1st part) | 0.69 | 0.48 | +1dB | +26dB | 29% |
| Polish (2nd part) | 0.71 | 0.51 | +6dB | +23dB | 43% |

Annex 2 is similar to the existing method; however, the limit is 'no exceedance of the background level' rather than 10dB or more. This element predicted nuisance in all of the samples, whereas only 29% were subjectively assessed to be noise nuisances.

The second element of the IOA Good Practice Guide on the control of noise from Pubs and Clubs – Draft Annex 2, which is based on 1/3 octave bandwidth analysis, produced the strongest statistical relationship between the subjective and objective levels (a correlation coefficient of 0.74 and degree of explanation of 0.54). Regression analysis of the sample indicated that the limit value of no exceedance of the background was set too low and that an increase of 32dB better represented nuisance conditions. Accordingly it was not surprising to find that this element of the criteria also predicted nuisance in every sample, thereby concurring with the subjective assessment only 29% of the time.

The loaded A-weighted assessment method resulted in a slightly stronger statistical relationship with the subjective level but performed less effectively as a predictor of nuisance.

The assessment using the German criterion DIN 45680 was found to concur with the subjective assessment in 82% of the sample, significantly more than any other criterion. This criterion's effectiveness was due, in part, to the limit value of 25dB which accurately described

the level above which nuisance occurred. A regression analysis of the sample produced a limit value of 26dB thereby confirming the accuracy of specified limit value. Using the German criterion, the objective levels were found to have a moderately strong statistical relationship with the subjective levels.

The Danish criterion predicted nuisance in all of the samples as the limit value was too low.

The first element of the Polish criterion similarly predicted nuisance in all of the samples; the second element performed slightly better resulting in a 43% concurrence with the subjective assessment. Use of both elements resulted in moderate to strong statistical relationships with the subjective assessment.

Conclusions

Of the selected criteria, it was found that the German criterion, DIN 45680, performed best as a predictor of noise nuisance due to entertainment music. The strongest statistical relationship between the objective and subjective assessment levels was found when using the 1/3 octave bandwidth analysis element of the IOA Good Practice Guide on the control of noise from Pubs and Clubs – Draft Annex 2.

It was recognised that the statistical validity of the results may be limited due to a relatively small sample

size. Nevertheless the results indicated likely trends and may contribute to further research toward the development of a scientifically robust assessment criterion for entertainment music.

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