ANALYSIS, IDENTIFICATION AND TREATMENT OF LOW FREQUENCY NOISE SOURCES ASSOCIATED WITH COMPLAINTS AGAINST REGULATED INDUSTRIES

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ABSTRACT
The aim of this paper is to extend the work of the University of Salford in the 'Defra NANR45 Procedure for the assessment of low frequency noise complaints' to the regulation of noise from industrial sources by the Environment Agency. Details are presented of three case studies in which residents had registered complaints against industries permitted by the Environment Agency. The use of synchronised noise meters to scrutinise potential noise sources is demonstrated. In a particular advance on the NANR45 procedure, a novel application of correlation analysis between the subjective rating recorded in the complainant's log and the exceedance over the NANR45 criteria is described to examine frequencies likely to be the environmental source triggering complaints. Appropriate noise control solutions to address identified sources using the preferred 'noise control at source' approach are illustrated. It is concluded that these techniques and analyses provide a useful complement to the NANR45 procedure by extending its applicability to the investigation and identification of noise sources where an environmental source has been found to be responsible for the low frequency noise complaint.

1 INTRODUCTION

In recent years much progress has been made in the assessment of Low Frequency Noise (LFN) complaints. Perhaps the most useful outcome has been the research funded by Defra resulting in the NANR45 procedure[1] following the review of published research by Leventhall et.al[2]. The main purpose of the NANR45 document is to assist Environmental Health practitioners to handle LFN complaints as efficiently and proficiently as possible. In particular, it aims to assist them to identify cases where no environmental sound is present that could account for the complaint. In those circumstances remedial action is beyond the remit of the Environmental Health practitioner. Field trials of NANR45[3] reported an environmental sound to found to be responsible for the LFN complaint in two out of ten cases, a figure that is commensurate with the results of various international studies, such as Pedersen[4] investigating whether it is real physical sound or low frequency tinnitus that causes the annoyance. Other work funded by Defra since NANR45 has perhaps understandably therefore been directed at coping strategies for sufferers[5].

This paper however concerns the cases where an environmental source has been found to be responsible for the LFN complaint. In many cases, environmental health practitioners will find a noise source above audible thresholds that clearly correlates with the complainant's log, typically an industrial process of some kind, fans, pumps or electrical equipment. Crucially there will also be correlation with the complainant's log. In these instances there is little formal guidance available to assist in an investigation to identify and treat low frequency noise sources responsible for complaints. Nevertheless this is often the position in which the specialist noise team at the Environment Agency (EA) finds themselves.

As a partner with Defra it is appropriate for the EA to adopt the LFN procedure presented in NANR45 for the investigation of LFN complaints. It must be noted though that the NANR45 criterion curve is provided as guidance for the evaluation of a LFN complaint, and not as an absolute limit. The EA is the regulatory authority for Schedule 1, A1 installations and waste facilities that fall within the Environmental Permitting Regulations 2010. This includes regulating environmental noise pollution from these sites. Although NANR45 frequently mentions Environmental Health Officers

(EHOs) as a potential audience, in 2008 Defra removed the ability of EHOs to enforce Statutory Nuisance against installations and facilities that are regulated by the EA[6]. This area of noise regulation then became the responsibility of the EA.

The EA regulates these sites by requiring the operator to comply with the conditions set in a written permit. With respect to noise, the standard permit condition reads:

Emissions from the activities shall be free from noise and vibration at levels likely to cause pollution outside the site, as perceived by an authorised officer of the Agency, unless the operator has used appropriate measures, including those specified in any approved noise and vibration management plan, to prevent or where that is not practicable, to minimise, the noise and vibration.

For the EA to take enforcement action against this permit condition, it must therefore demonstrate that:

- the noise is likely to cause pollution
- the noise is coming from the permitted activity
- an EA Officer has perceived the noise
- the operator has failed to use appropriate measures to prevent or minimise the noise

This paper will present examples of how the EA has taken action under such circumstances. Three case studies are presented, each following the chronology of events. Typically this chronology is as follows:

i. the Environment Agency receiving a complaint,
ii. substantiating that complaint,
iii. indentifying the source of the noise,
iv. identifying appropriate mitigation, and
v. influencing the site operator to apply that mitigation.

Each case study will describe how NANR45 was applied for the investigation of an LFN complaint directed at an installation or facilities regulated by the EA. Next the steps taken beyond NANR45 where appropriate to resolve the problem are detailed.

2 EXAMPLE 1: AN ANIMAL FEED MILL

2.1 Description of the case

The reporter alleged a low frequency noise pollution from a large animal feed mill that was 350m away and was in continuous 24hr operation other than on Sunday daytimes and nights. The animal feed mill was within a large industrial estate that was immediately adjacent to a large housing estate, see Figure 1. The feed mill was a significant noise source for the immediate residents, but was not causing complaints. This was perhaps due to the mill being at this location long before any housing development. The complainant appeared very anxious and lived in a stressful environment. No-one else in the household or immediate vicinity could hear the same low drone as the complainant.

2.2 Investigation of potential low frequency sources

Two synchronised noise meters were used to enable a positive conclusion as to whether or not the mill was the source of any LFN pollution at the residence. Meter 1 was placed on the roof of the mill, on the side that faces the complainant, see Figure 2. Meter 2 was placed in the complainant's bedroom, which faces the mill. The resident was able to trigger an audio recording at her discretion.

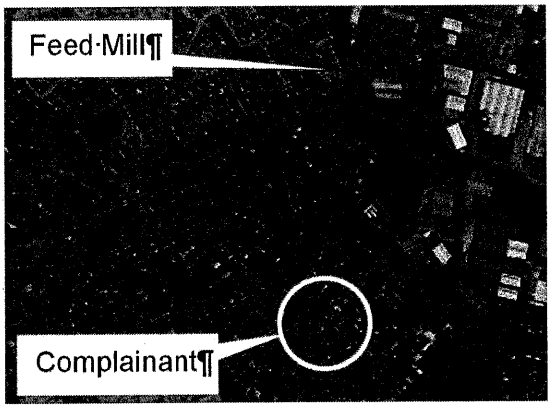

Figure 1: Aerial plan of location

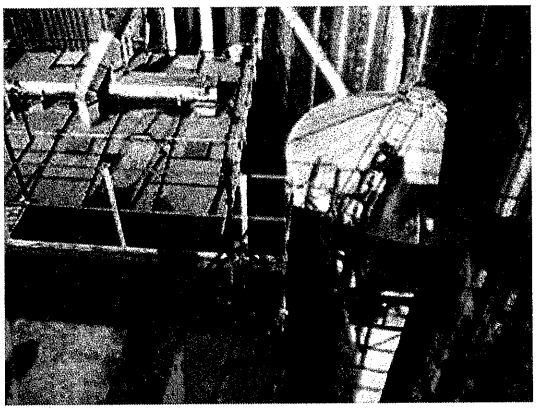

Figure 2: Noise meter 2 located on mill roof

The data showed a regular 50Hz tone at the residence, which did not match the 125Hz tone that was from the mill which was associated with the product drag lines. None of the residential noise levels exceed the NANR45 criteria, and noise recordings were even triggered when the site was shut. An example 1/3 octave spectrum is presented in Figure 3. This 50Hz tone is thought to have been from a domestic fridge pump.

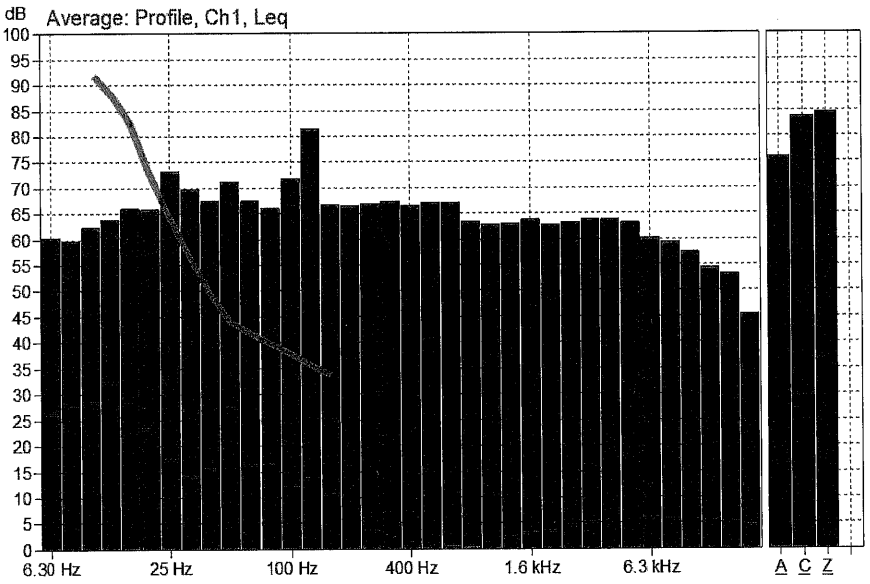

Figure 3: 1/3 octave levels showing residential (green), mill (red) and NANR45 criteria (blue)

2.3 Analysis

The 50Hz tone was found to be 16dB below the NANR45 criteria, and was inaudible in the recordings. The levels were generally at or below the rated noise floor of the meter. It was expected that these levels were also inaudible to the complainant, and that the complaints are more likely to be associated with tinnitus.

3 EXAMPLE 2: A MILK PROCESSING FACTORY

3.1 Description of the case

A resident complained of a low frequency rumble that he believed to be coming from a milk processing factory that was 120m away. The resident had started a website that was very antagonistic to the factory, and he was canvassing support from the local population.

3.2 Investigation of potential low frequency sources

A single logging noise meter was put in the complainant's bedroom, which had a grazing line of sight to the factory. As illustrated in Figure 5, levels here showed regular 5-10dB exceedances of the NANR45 criteria at 100Hz. Subjectively, the audio recordings sounded like a bulk air handling unit rather than mains hum, a common source of 100Hz noise.

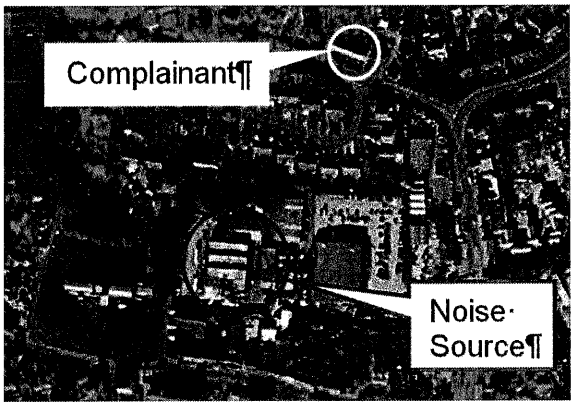

Figure 4: Aerial plan of location

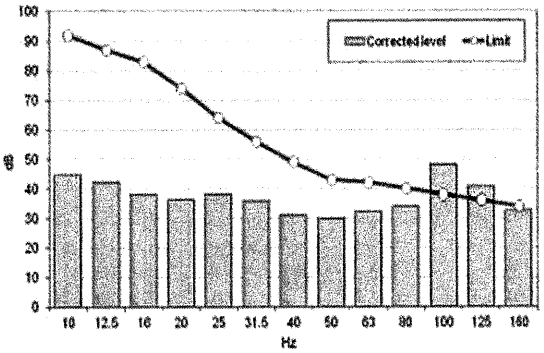

Figure 5: 1/3 octave analysis

Whilst the NANR45 investigation was still ongoing, the resident independently arranged for the site manager to visit his house at night, and for different site processes to be sequentially switched off. This clearly indicated to the resident and the site manager that the noise source was the site's large boilers. These boilers had recently been changed from being oil fired to gas fired to reduce air pollution. The boilers were later temporarily changed back to oil, and the low frequency noise levels reduced.

3.3 Analysis

The reason for the greater noise from burning gas instead of oil was probably due to the natural gas (predominantly methane) having a faster flame velocity than the larger hydrocarbons found in kerosene[7]. This could then be exciting one of the acoustic modes of the boiler furnace. It is very difficult to predict the frequency of this mode as there will be dynamic changes and gradients in gas density, velocity and temperature within the furnace. These changes also resulted in peak frequencies that varied between 95Hz - 108Hz at the boiler exhaust, but were fixed at 75Hz at the burner plate. Thermoacoustic vibrations, where the furnace behaves like a Rijke or Sondhauss tube[8], can be ruled out as the temperature gradients from burning oil and gas are essentially the same.

The flame plate in the boiler where the flame is 'held' was moved further away from the fuel jets to improve the fuel mixing prior to ignition. This resulted in a 3dB reduction, which was likely due to improved flame stability. Further attenuation was required, and the operator chose to install a large absorptive silencer (3.8m long and 0.5m across, with an inner annular ring) which resulted in a dynamic insertion loss of 25dB at around 100Hz, as shown in Figure 6. Following these modifications no further complaints were received.

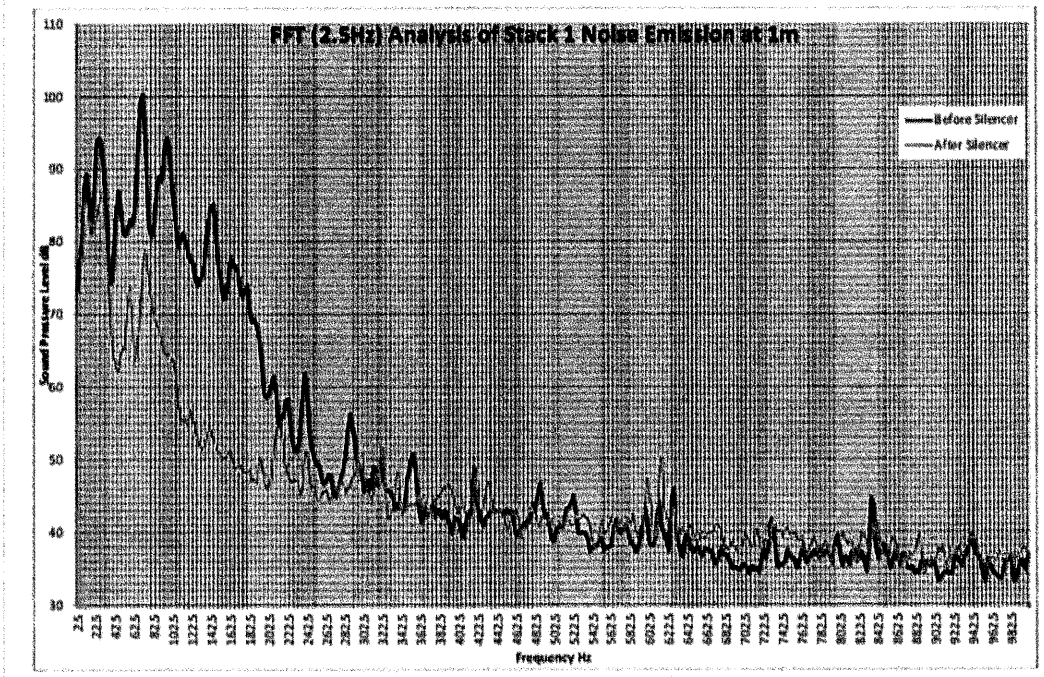

Figure 6: FFT at 1m from exhaust, before (blue) and after silencer (green) installation

4 EXAMPLE 3: A MATERIALS RECYCLING FACILITY

4.1 Description of the case

A resident complained of a low frequency noise that she believed to be coming from a materials recycling facility that was 1000m away. The resident was extremely anxious, and was threatening suicide. The proposed source of the noise was three large centrifugal fans that extracted air from the waste processing halls. The NANR45 interview showed elements that were common to tinnitus, for example that the noise was not attenuated by ear plugs. However, other elements were common to noise pollution, for example that the noise was not present in other locations.

Any noise from this location might have been expected to be reduced by 60dB due to geometric spreading, with air absorption and terrain possibly providing a further 10-15dB attenuation. Together with an estimated partially open window correction of 10-15dB[9], this suggests the noise source to have SPL at 1m of 118-128dB at 100Hz. Noise sources of this magnitude were uncommon, but due to the high risk presented by the resident, noise monitoring was performed for a period of 1 week.

4.2 Investigation of potential low frequency sources

Meter 1 was placed in the front bedroom. The predicted room modes in this location included 98Hz and 100Hz, and a distinct flutter echo was present. A 100Hz hum could be heard coming from the mains, which disappeared when the electrics were turned off. The resident was adamant that the same noise was present when the electrics were turned off. Meter 2 was placed on a 5m screening bund on the site perimeter, which was on line-of-sight between the proposed source and the complainant. These locations are shown in Figure 7.

Figure 8 shows the 1/3 octave levels found during one of the noise diary entries, and Figure 9 shows the 100Hz 1/3 octave band during the same event. In both figures the upper (red) levels are at meter 2, and the lower (green) levels are at the residence.

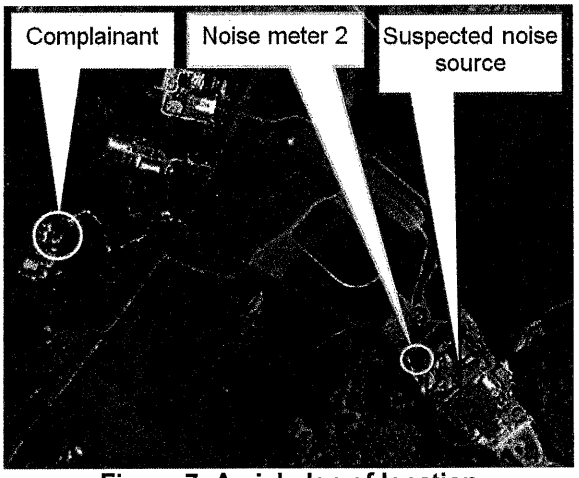

Figure 7: Aerial plan of location

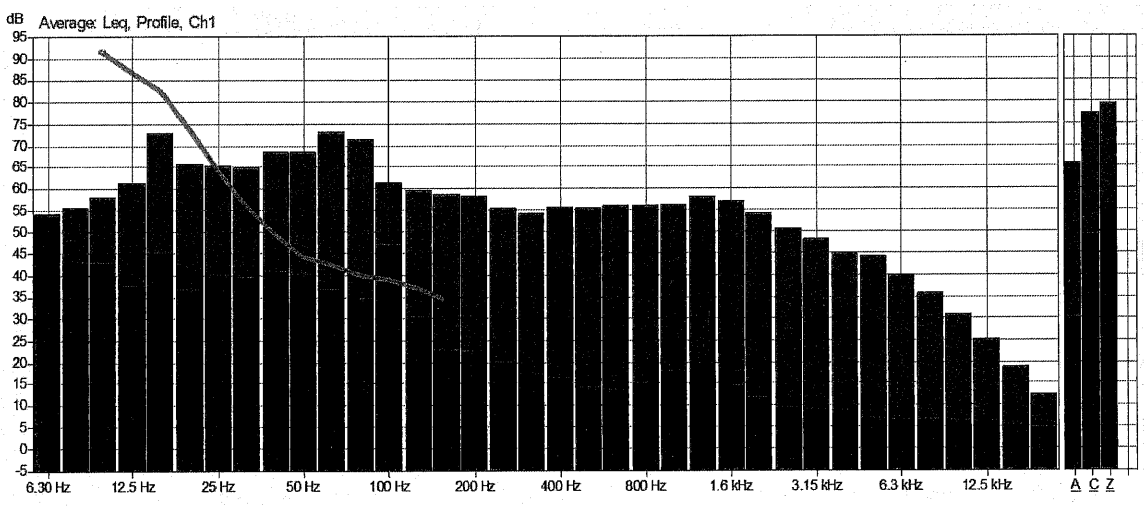

Figure 8: 1/3 octave levels during a noise diary event showing a pronounced 100Hz tone. Meter 2 (Red), Residence (green), NANR45 criteria (blue)

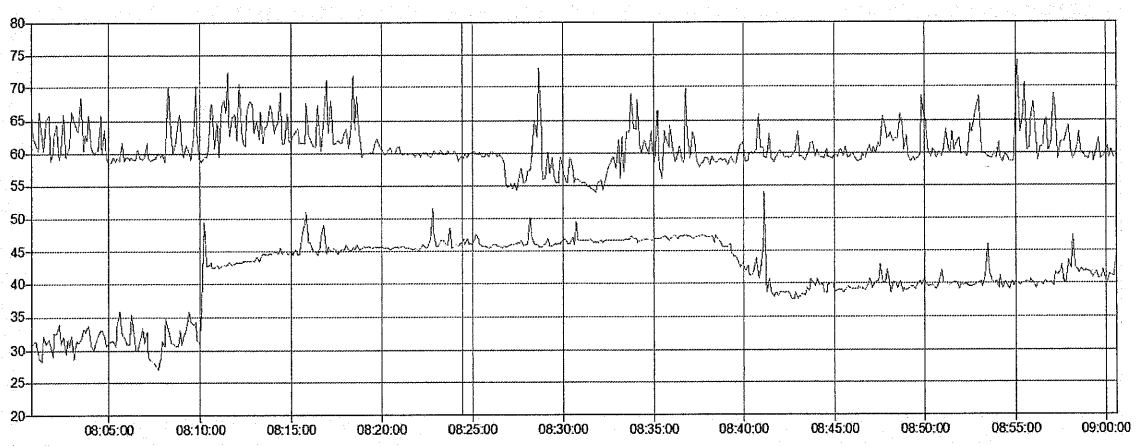

Figure 9: 100Hz 1/3 octave band for the same noise event showing step changes at residence. Meter 2 (Red), Residence (green)

The noise diary kept by the resident noted 29 noise events. Of these 29 events, 14 found tonal LFN that were up to 9.4dB above the NANR45 criteria at 100Hz, and 2 that were below the NANR45 criteria at 100Hz. There were also 5 tonal events that were below the NANR45 criteria at 50Hz. The other 9 events were unsubstantiated. These data are discussed below.

4.3 Analysis

Figure 10 shows the NANR45 criteria exceedances versus time of day. This shows that (1) none of the 50Hz events exceed the NANR45 criteria, that (2) the NANR45 criteria are most commonly (and significantly) exceeded during the daytime, and (3) that none of the 50Hz events occurred in the daytime.

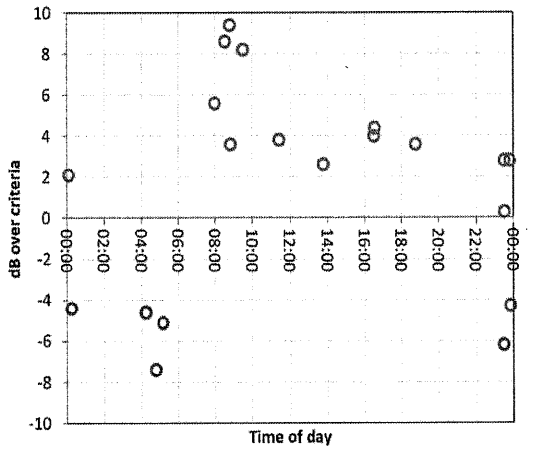

Figure 10: NANR45 exceedances v time of day. 100Hz events (green), 50Hz events (red)

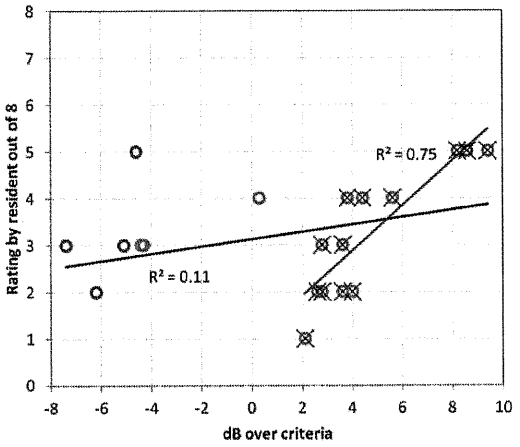

Figure 11: NANR45 exceedences v perceived noise level

Figure 11 shows the NANR45 exceedance versus how loud the resident perceived the noise to be (out of 8). This initially shows a very poor correlation of R^2=0.11. When the exceedences <1dB are excluded this correlation improves to R^2=0.75, which given that the resident only used integers to rate the noise is as good a correlation as can be expected. What this analysis shows is that (1) a low frequency noise is not always present when the resident believes it to be, and (2) when a low frequency noise is present (>1dB over the criteria), the resident is responding in strong correlation to the noise level.

These results indicate that (1) a 100Hz tone is present that regularly exceeds the NANR45 criteria, but is clearly not from the proposed waste recycling facility, and (2) that there are other perceived LFN events that are not linked to an exceedance of the criteria, which are possibly attributable to stress induced tinnitus (possibly due to the stress of the occasions when the 100Hz tone is present). The source of this 100Hz tone is likely to be associated with mains hum.

5 CONCLUSIONS

The use of synchronised noise meters to scrutinise potential low frequency sound sources was found to be an efficient and cost effective investigation technique. However, formal guidance on appropriate investigation, analysis and 'noise control at source' solutions to address low frequency sound sources is required.

The application of correlation analysis between the subjective rating recorded in the complainant's log and the exceedance over the NANR45 criteria was found to be effective in the investigation of frequencies likely to be the environmental source triggering complaints. This is a particularly useful advance on the NANR45 procedure.

Further work is required to extend the work of the University of Salford presented in the 'Defra NANR45 Procedure for the assessment of low frequency noise complaints'. For the majority of cases where no environmental source is found that could be responsible for the complaint, a complement to the procedure would be the development of techniques by which the sufferer might acquire a degree of control over their adverse reactions. The application of neuropsychological understanding of human hearing and tinnitus to LFN complaints, as proposed by Moorhouse and Baguley[10], would allow referral of appropriate LFN cases to strategically located audiology departments. Such a network could be established by providing specialist audiologists with some additional background knowledge about LFN.

References

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