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PROBLEMS IN THE ASSESSMENT OF LOW LEVEL LOW FREQUENCY NOISE

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Relating the intensity of a sound to a subjective annoyance value has remained a central problem for those concerned with the assessment of noise. Parameters have been adopted in an attempt to tackle this problem and these include: perceived noisiness (PNdB), equal loudness contours (phons), ISO noise rating curves and dB(A). A brief outline of the assumptions and procedures upon which these measures are based will follow. Some points on why it is thought that low frequency (20-150 Hz) noise problems may pose particularly difficult questions for these measures to answer will be discussed with suggestions of how subjective response ratings combined with stress levels could serve to supplement low frequency noise criteria.

The intensity of a sound refers to its physical magnitude which may be expressed in terms such as power or pressure. The subjective perception of intensity is known as loudness and is usually expressed in terms derived from equal loudness contours. Early researchers found the auditory phenomenon of loudness to be a rational starting point in quantifying the subjective effects of sound (Stevens, 1936). The discovery that subjects were able to consistently estimate the relative loudness over the frequency range 20Hz-15KHz reinforced the preoccupation with intensity. However, later researchers have argued that this discovery could have alerted us to a complex characteristic of audition, in this case, that of acoustic coding and recall. Yet, intensity retained its central role in the assessment of noise.

When the relationship between intensity and loudness became juxtaposed with the proposition that the hearing mechanism's predominant characteristic revolved around responding to SPL's above its threshold and not to those below it, a powerful noise assessment method developed. It led to a number of derived connections which still persist, for example with the interference of speech, sleep; and loudness with annoyance.

The allocation of a noise value (NR), to an environment which requires verbal communication, based upon SPL dB at which speech becomes intelligible may still lead to a drop in individual efficiency, or performance maintained (short-term) at the cost of increased stress levels. The working assumption seems largely to have been one where the highest intensity above the thresholds involved were seen to be the most relevant. Clearly, we are not concerned here with SPL's which would simply prohibit communication. The point is that such assessments of environments based on, for example, articulation scores related to SPL values in octaves, may underestimate the auditory system's capacity to cope. Whilst over-estimating or ignoring the individual's ability to make the correct decisions and produce the appropriate behaviours may also happen in the case of such assessments.

The auditory system's capacity has been shown to be extremely complex and extensive. Work at the Bell Telephone Laboratories has shown that using high, low and band-pass filters with variable cut off frequencies, that virtually no particular frequency components were essential for speech recognition. While Moray (1972) reports a phenomenon known as the 'pulsating threshold' which provides an example of a person hearing a word even when acoustic cues are minimal. Finally, Cherry (1953) has argued that as verbal communication is in a linguistic context, the auditory system displays a clear ability to process incoming stimuli and to establish 'transitional probabilities' between one word and the next.

The commonly used NR curves assume that the highest frequencies will be more annoying than the lower frequencies. This seems to indicate a loudness and noisiness equivalence, which will be discussed at a later stage. Hopkins (1969) reports that a person is more likely to be disturbed during a REM period of sleep by low frequency noise than by other types of noise.

RESPONSES TO SOUND

For practical purposes the most important characteristic of sound was seen to be that which induced the auditory sensation of loudness, namely its intensity.

The ear displays a frequency dependent response to 'sound' and exhibits a maximum sensitivity region between 1 KHz-4 KHz. Therefore, consequent upon an intensity would be a subjective response; a consideration of the ear's sensitivity region would permit a level of certainty about the extent of the response. A higher intensity would elicit a greater response and if this response was annoying, it would be accentuated by a further increase in intensity. Therefore, these 'noises', which are, in general, of a lower intensity and concommitantly smaller subjective response, will produce a lower annoyance/loudness value. As the hearing thresholds were less sensitive at lower frequencies, it was to follow that at lower frequencies, a markedly increased intensity would be required to induce a comparable amount of annoyance/loudness. Kryter (1970) has pointed out that many concerned in the analysis of noise have taken these assumptions to mean directly that low frequencies are in 'character' less likely to annoy than higher frequencies.

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Loudness then, has been assumed to be a reasonable guide to the annoyance of a sound. It has been shown by Reese et al (1944) that for a variety of sounds the judged phon levels were significantly different from equal annoyance contours although this was not true for broad-band sounds. An indictment of using the parameter of loudness seems to be that it does not respond significantly to either spectral complexity or duration. While Pearsons and Horonjeff (1967) have found that even the wording of instructions can significantly effect ratings of loudness, to signalling a difference from annoyance.

Equal noisiness contours were developed in an attempt to produce relevant guidelines with respect to noise. The procedure adopted resembled, in many ways, that employed for equal loudness contours, with an exception in that the reference point was a centre frequency. Essentially, this meant that curves could be produced by relating the intensity of bands of random noise to their band centre frequencies, at the point that they were judged to be equally 'annoying'.

This procedure removes the individual from the normal type of environment in which, in this instance, the auditory system has to operate. It was Broadbent (1960) who pointed the way to accurately assessing the effect of a sound as a noise. One of the assessment factors in Broadbent's experiment being a decrement of efficiency during work or during the performance of a task. He recognised that audition is constantly processing out (habituation, attention and concentration) interference, much more than it permits through as an operational variable.

It is suggested that noise assessment criteria should optimally be cognisant of three aspects, namely: source (SPL Hz), behaviour (appropriate/inappropriate) and situation (information content). Further, it is also recommended that assessment of noise requires monitoring of body responses (stress indicators), task performance scores as well as subjective rating scales.

Noisiness contours may be limited by their methodology, yet they have been employed for over 15 years and used in numerous cases, in an attempt to provide some noise value for a given sound. However, with respect to low frequency noise, the attempt made has been at most minimal. For it should be noted that researchers have historically, on average, excluded frequencies below 70 Hz and SP levels below 64 dB, when establishing PN contours. A notable exception being Pearsons and Kryter. Their study, between 1959-1962 included frequencies down to 40 Hz.

The problems facing those concerned with assessing the effects of low frequency noise are further compounded by the wide usage of dB(A). This particular weighting system is largely regarded as mimicing the sensitivity of the human ear (the shape being based on a 40 phon contour) and therein attenuates low frequencies. The arguments against the use of dB(A) for low frequency measurements are many, for example Leventhall (1980), Chatterton (1980) and Tokita (1980). In brief, dB(A) exemplifies the simple threshold notion of detection and annoyance and permits little consideration of low level/low frequency sounds, or of the manifest cognitive complexities of audition.

CONCLUSION

So, is there enough evidence to justify interest in low frequency noise problems ?

The recent work of Cardozo and Lieshout (1981) studied the 'sound character'. Although spectra were not published, a brief analysis of their data indicates that those sounds receiving highest annoyance values were either low frequency or weighted with cognitive values, for example a baby crying. Both of which are avoided by dB(A). Their study may serve to indicate the relevance of 'sound character' to noise assessment as opposed to simple intensity levels.

Another interesting study by Tokita (1980) investigated complaints about low frequency noise (2-90 Hz) which were predominantly at SPL's as low as 65 dB. The complainants exhibited symptoms of sleep disturbance, irritation, headaches and a sensation described as 'oppressive' and heavy. These symptoms seemed to diminish with an increase in SPL. This again makes little sense in terms of a dB(A) conception of annoyance. Numerous examples of similar investigations and well documented lists of the symptoms exhibited by complainants clearly necessitates further investigations.

The data so far presented gives some of the reasons why it is felt that much research is called for in the development of valid low level/low frequency criteria. In an attempt to escape some of the problems which previous assessment procedures have suffered, it is intended to pursue the three criteria mentioned earlier. It has been noted that many symptoms related to this form of annoyance are classic stress symptoms. It seems sensible, therefore, to utilize modern physiological techniques in an attempt to establish reasonable criteria for assessing the effects concomitant with low frequency noise in an environment consisting of behaviour, task and situation.

Outlines of physiological monitoring techniques will be given at the forthcoming conference.

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