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Environmental Noise Impact Assessment

Europe moves to harmonise methods of assessment by bringing predictions and measurements closer together

Environmental noise has always been with us, from the dramatic results of thunderstorms, to the gentle rustling of leaves by the wind. There are more frequently encountered natural sources too, such as water flowing in streams, various animal calls, and the dawn chorus as birds welcome the rising sun. However, with the advent of the industrial society there has been an explosion in the number of man made sources; ever since man started to use primitive tools, noise has been the unwanted side effect.

Of course, not all noise is unwanted: the creation of music has given mankind one of its most abiding pleasures. Conversely, while mechanised transport has transformed our way of life, the associated noise is an unwelcome by-product, both to the traveller and to those affected. Nearly all industrial processes, whether it be food, clothing, tool or toy production, mineral extraction or waste disposal, involves the use of noisy machinery. The culmination of all this noise has come to be known as "Environmental" noise when measured outdoors. By implication, any sound that is created but is not welcome, whether it is a distant rock concert, or a local factory, road, or airport, has an impact on others and may need controlling and monitoring. This is the essence of Noise Impact Assessment.

Measurement of noise and noise units

Noise is created by causing small fluctuations in air pressure. These fluctuations are generally caused by vibrating surfaces. An obvious and common example of this is a loudspeaker, which generates sound intentionally, by exactly these means. The range in level of these fluctuations is extremely large, extending from the inaudible, to levels which would instantly cause hearing damage.

Employees in the production part of an industry should know which discharges to the sewer system will negatively affect a biological system. If an incident happens, they must immediately warn the plant operators.

Lack of oxygen reduces the activity of the aerobic floc forming bacteria, which means that the nutrients remain available longer for filamentous species. Maintaining complete aerobic conditions in the entire sludge floc requires an oxygen concentration of 2 mg/l in the bulk liquid in the aeration tank. Lower concentrations will often stimulate filamentous growth, especially in fully loaded plants.

There is a rule of thumb for the required BOD:Nitrogen:Phosphate ratio: 100 : 5 : 1. Lack of nitrogen or phosphate is responsible for bulking occurring in many industrial waste water treatment plants. More rarely, lack of micro-nutrients may play a role, which can be solved by dosing commercially available nutrient-mixtures.

Waste water rich in reduced sulphur compounds will nearly always stimulate growth of filamentous Thiothrix species. Solving bulking caused by Thiothrix requires the removal of these reduced sulphur compounds, for example through pre-aeraration, before the influent enters the aeration tank.

Three alternative routes remain when bulking cannot be solved by the measures mentioned so far. In contrast to domestic waste water, most industrial effluents contain a very large fraction of water soluble and often easily degradable compounds. It seems likely that many unknown filamentous morphotypes, just as it has been ascertained for most known species, use this fraction for their growth. When this fraction is largely removed before the flow enters the aeration tank, the chance on bulking occurring,is greatly reduced. The soluble fraction can be removed largely through the incorporation of a highly loaded tank in the process line upstream of the aeration tank. Filamentous species do not grow fast enough to maintain themselves in such a highly loaded tank. Again, three options can be distinguished.

- *A two-stage anaerobic-aerobic configuration is a well known process. It prevents an excessive growth of many filamentous species, but will often not solve bulking problems caused by e.g. Haliscomenobacter hydrossis or Nocardioforms*
- *A two-stage aerobic-aerobic activated sludge configuration with intermediate sludge settling and recycling is a known process as well. Aerobic-aerobic is also applied in the combination of a trickling filter plus a low loaded activated sludge tank as a second stage*
- *Largely removing the soluble influent fraction can also be accomplished through incorporation of a highly loaded aerated tank without sludge settling and recycling as the first stage. The aerated liquor remains for about six hours in this tank and, subsequently, flows without settling directly into the aeration tank of the second stage. This relatively cheap solution has been successfully applied in several industrial waste water treatment plants in The Netherlands*

The second main route concerns the application of so-called selectors. Aerobic, as well as anoxic and anaerobic selectors can be distinguished. In contrast to the previous options, the highly loaded selector is not a separate stage but more or less part of the aeration tank. Favouring floc-forming bacteria in their competition with filamentous bacteria for the available substrate is the aim of applying selectors. Selectors will not be effective with filamentous species characterized by their large substrate storage capacity. It is always recommended to start with a pilot plant before control methods, which require reconstruction of the plant, are applied on a full scale. The third main route for improving the settling velocity of activated sludge concerns the application of chemicals, either aimed at the destruction of the filaments or to improve the size or the weight of the flocs. This is only a temporary solution for settling problems, but might be required when bulking results in serious loss of biomass from the plant and immediate action is required. ■

References

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Author

Dick H. Eikelboom has been involved in biological wastewater treatment since 1970. He is an expert on filamentous bulking, the causative micro-organisms in particular. In 1999 he started a small private company (ASIS), in which new information is made accessible to those working in the field.

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The human ear is a very sophisticated sensing instrument which allows us to hear all the sounds which are useful to us, but which can be damaged by very high sound levels. Experimental work has shown that the smallest acoustic pressure that is generally audible to young, healthy ears is about 20μPa and this value has been adopted by international standards as the reference level for scientific measurements. The dynamic range of noise levels experienced in everyday life is extremely high: the popping of a balloon can generate levels as high as 200,000,000 μPa. This large range of numbers is dealt with conveniently by using a decibel scale where a sound pressure level [dB], is defined as

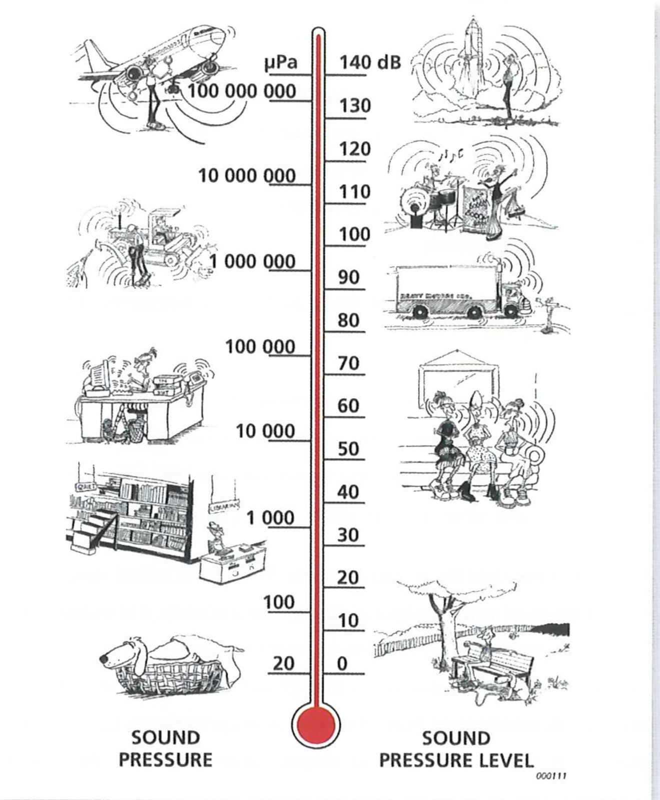
$$L = 10\log_{10} \frac{(\text{sound pressure})^2}{(\text{reference pressure})^2}$$

and the reference pressure is 20μPa.

It is important to note that the sound pressure has been squared. This is because the human ear reacts to the energy level of the sound. A negative dB level is simply a noise which is below 20μPa, although this would not be audible to most of the population.

Thus, the balloon popping at 200,000,000μPa can be expressed as a level of 140 dB re 20μPa, and a busy office where there is a noise of 35000μPa can be expressed as 65 dB re 20μPa. As the decibel scale is simply a ratio, it should strictly be quoted with the reference value.

Figure 1. The range of sound pressures experienced in everyday life and the Sound Pressure Levels in decibels (after Brüel and Kjaer)



However, it is common practice to refer to sound pressure levels in dB without specifying the reference value, which is then assumed to be the standard 20μPa, and this will be the convention throughout the rest of this article. An illustration of the relationship between pressure and decibels is given by the "thermometer" scale shown in Figure 1.

As the decibel is an expression of a ratio, it can also be used to indicate level changes. Hence, if the level at night somewhere in the countryside is around 10 dB, and it increases as the sun rises to 35 dB, we can say that the dawn chorus has caused an increase in the level of 25 dB.

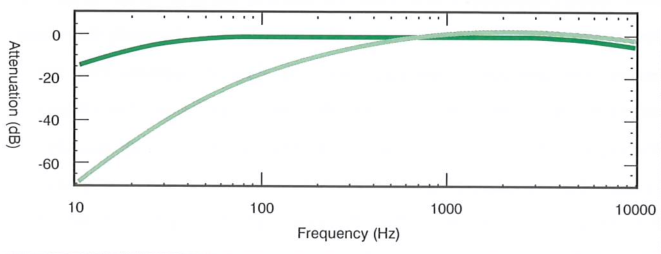


Figure 2. Comparison between A-weighting and C- weighting

Human hearing is not equally responsive to sound pressure at all frequencies. In general, low frequencies do not sound as loud as the mid-range frequencies from 500 Hz to 5 kHz. Above 5 kHz the ear is also less sensitive. The degree with which the sensitivity varies is dependant on the sound pressure level, but these variations have been standardised, with a series of "weighting" curves, which are applied to the measured sound signal before any further analysis. The most widely applied weighting curve is A-weighting. This is used for almost all environment noise measurements and is shown in Figure 2. The C- weighting, also shown in Figure 2 is intended for use at higher levels of noise, and gives much less attenuation at lower frequencies.

Noise can also be analysed for frequency content. In environmental noise assessments, this is primarily used to establish the presence, or significance, of prominent levels of noise confined to narrow frequency bunds, called tones. The frequency analysis can be carried out in narrow bands, with a constant bandwidth per band across the whole frequency range; alternatively the analysis can be done with a constant percentage bandwidth analysis, where the bandwidth increases geometrically with increasing frequency. This is normally performed as an octave or one-third octave analysis. In an octave scale each band centre frequency is double the centre frequency of the band below, and the bandwidth of each band is also double the bandwidth of the band below. One-third octaves are an extension of this idea fitting three bands into each octave, allowing better frequency discrimination. The one third octave band also matches closely some of the physical characteristics of the human ear. Figure 3 shows a frequency analysis of the signal in Figure 4, for both narrow band and one third octaves. >

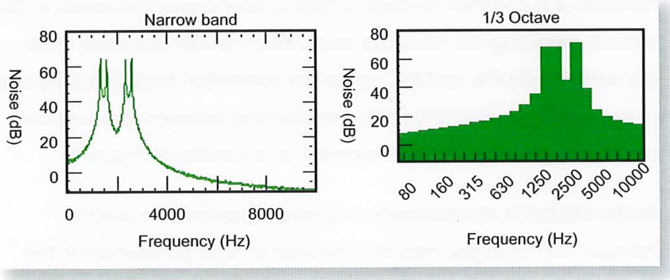


Figure 3. Frequency analysis of a signal in narrow band and in 1/3 octaves

Although the sound pressure level is the most widely used quantity for the measurement of noise, there is an increasingly sophisticated set of alternative parameters which can be used to express noise levels. Very few noise sources produce noise at a steady level; typically the noise levels from any source will vary over time. Even if relatively long term averages are used, say one-hour intervals, noise levels may change throughout the day so there will be a large variation in the recorded levels. Noise measurement parameters are used to quantify aspects of the variation in noise level. It is, therefore, as important to understand the significance the parameter being used to describe a noise level, as it is to measure it in the first place. Figure 4 shows a typical example of the pressure waveform an environment noise signal. Note that the maximum pressure could be positive, or negative, but when converted to decibels the pressure is squared, giving the same dB level for a negative or a positive peak.

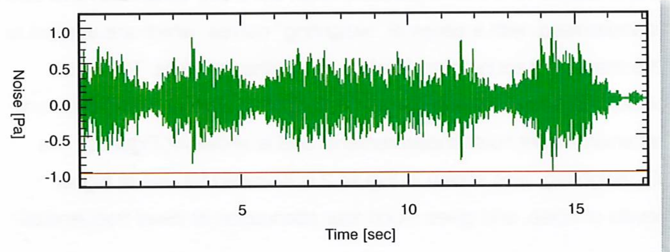


Figure 4. An example of environmental noise

The red line shows maximum peak sound pressure, during the measurement period. (1.02Pa is equivalent to L_{maxp} 94)

Figure 5 shows a range of noise parameters derived from the noise signal.

Other parameters are:

$L_{Aeq,T}$ **=75.5** Equivalent continuous "A" weighted Sound Pressure Level, for time, T. This is the level, which, if it were constant over the same measurement period would have the same energy as the original signal. Thus the $L_{Aeq,T}$ represents the overall energy of the signal for a given duration, T.

L_{AF} "A" weighted Sound Pressure Level, with a Fast (F) time weighting.

The F time weighting is an exponential weighting applied to the varying sound pressure level in order to display the level of variation. Originally designed for old-fashioned meters with needles, it enables the observer to understand the characteristic of a noise.

L_{AS} "A" weighted Sound Pressure Level, with a Slow (S) time weighting. The S time weighting is an exponential time weighting with a longer time constant for use when the variations in the noise level are so rapid that they cannot be observed easily with F.

L_{AFmax} **= 81.4** The maximum value of the "A" weighted Sound Pressure Level, with a Fast (F) time weighting during the measurement period

L_{ASmax} **= 78.1** The maximum value of the "A" weighted Sound Pressure Level, with a Slow (S) time weighting during the measurement period

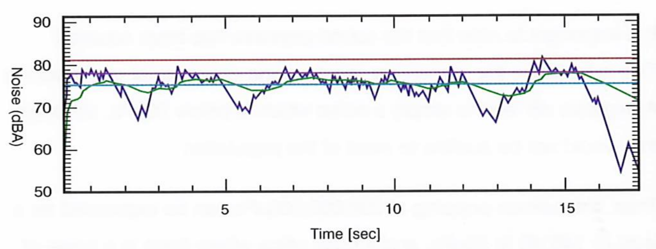


Figure 5. Noise levels and associated parameters

Finally, a noise signal can also be analysed to obtain statistical parameters.

$L_{AF10,T}$ The "A" weighted Sound Pressure Level, with a Fast (F) time weighting exceeded 10% of the time period, T.

This parameter is used to characterise traffic noise, in particular. Measuring close to a road, the assumption is that the higher noise levels are caused by passing vehicles. On modern busy roads, the noise may be almost steady and statistical analysis loses its ability to discriminate successfully.

$L_{A90,T}$ The "A" weighted Sound Pressure Level exceeded for 90% of the time period, T.

The $L_{A90,T}$ parameter is used to characterise the "Background Noise". This is assumed to be the noise present when the more obvious noises are not present. Again this works well with intermittent noise, but is less useful when a noise under investigation is steady.

A further noise quantity is sound power. The sound power output LWA is a measure of sound output produced by a source; it is independent of the acoustical properties such as reverberation, of the environment in which the source is placed. Sound power is measured in watts (W), and the dB reference is 1pW. A simple analogy between sound power and sound pressure is that of an electric heater in a room. We may >

know we have a 2kW heater, but the temperature we experience will depend very much on the standard of insulation, and whether the door of the room is open etc. Similarly our ears respond to the sound pressure in a room, for a source of given sound power our perception of the noise level will depend on the size of the room and the amount of acoustic absorption, from soft furnishings and wall coverings.

Assessment methods

There are a number of reasons for carrying out a noise impact assessment. In the case of industrial development and infrastructure, the issue is whether the levels of noise introduced by the development will be acceptable. Most states have their own local legislation covering this issue, and there has been a considerable amount of international study defining the levels that are considered acceptable for certain activities and occupations, including leisure activities and residential use. The World Health Authority has issued a document entitled "Guidelines for Community Noise". This document gives guideline values for most land-use areas, including homes, schools, hospitals and open areas such as parkland. It also covers public spaces and work areas, but the limits in these areas are based on health and safety legislation relating to the possibility of hearing impairment. The WHO limits are based on $L_{Aeq,T}$ over defined periods, primarily making the distinction between night-time and daytime. There are also maximum allowable levels based on L_{Amax}. Table 1 shows the levels relating to residential use.

Generally speaking, local authorities specify maximum permissible existing noise levels for new residential developments at the planning phase, and the noise values which must not be exceeded at boundaries of industrial developments. There are international standards which define how these noise limits should be derived. The ISO 1996 series covers the measurement, definition, and application of noise limits. Most international limits are based on a noise rating level ($L_{Ar,T}$) over a time period, T. For instance, different noise ratings might apply during the day and at night, reflecting the guidelines in Table 1.

The rating level for any given period is given by

$$L_{Ar,T} = L_{Aeq,T} + K_1 + K_2$$

Where the K factors reflect the increased annoyance associated with tonal noise and impulsive noises.

K_1 is a tone adjustment. This is determined by frequency analysis as shown in Figure 3, and observation. The adjustment can be between 2 and 6 dB.

K_2 is an impulse adjustment. This is determined by comparing the L_{AI}, (the sound pressure level with an Impulse time weighting), or the L_{Amaxp} and the L_{Aeq} over the same period. The amount of adjustment allowed is not specified in the standard.

"where industrial noise sources are in a fixed location, the criterion is based on the difference between the "rating level" and the background noise"

Very often, the International Standards are condensed and simplified, for local use.

For instance, there is currently in England a Planning Policy Guidance tool "Planning and Noise", (PPG 24) issued by the Department of the Environment for the evaluation of noise exposure of proposed noise sensitive developments. For new dwellings PPG24 introduces the concept of Noise Exposure Categories (NEC) for residential development, encourages their use and recommends appropriate levels for exposure to different sources of noise.

Table 2 which is used as an example, shows each NEC band, defined by a range of 'free-field' noise levels, in relation to road traffic and mixed noise sources.

In addition there is a separate standard for assessing mixed residential and industrial development, BS 4142. This is intended to establish the likelihood of a noise complaint relating to a specific noise source. For industrial noise, where the operations are permanent and the noise sources are in a fixed location, within the boundary of the site, then the significance criterion is based on the difference between the "rating level" and the background noise.

The "rating level" is similar to the rating level in ISO 1996, and is equal to the $L_{Aeq,T}$ where T is 1 hour and modified to allow for any special characteristic of the noise, with a single factor, K. It is possible for the operational sound pressure level to exceed an L_{Aeq} noise level for a short period without the limit being exceeded. The rating level is the level of the specific noise, (relating to the source of concern), corrected for the residual noise. The residual noise is the noise when the specific

Table 1. Guideline values for residential properties (WHO guidelines)

Specific environment	Critical health effects	L_{Aeq}	Time base [hrs]	L_{AFmax}
Outdoor living area	Serious annoyance, daytime and evening Moderate annoyance, daytime and evening	55 50	16 16	
Dwelling, indoors	Speech intelligibility &moderate annoyance, daytime and evening Sleep disturbance, night-time	35 30	8 8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60

	Road traffic or mixed noise sources		
NEC	Daytime (07.00 - 23.00) L_{Aeq}, 16 hr dB	Night-time (23.00 - 07.00) L_{Aeq}, 8 hr dB	Planning Advice
A	<55	<45	Noise need not be considered as a determining factor in granting planning permission, although noise at the high end of the category should not be regarded as a desirable level.
B	55-63	45-57	Noise should be taken into account when determining planning applications and, where appropriate, conditions imposed to ensure an adequate level of protection against noise
C	63-72	57-66	Planning permission should not normally be granted. Where it is considered that permission should be given, for example because there are no alternative quieter sites available, conditions should be imposed to ensure a commensurate level of protection against noise
D	>72	>66	Planning permission should normally be refused

Table 2. The noise exposure categories used to guide planning officials in England (Reproduced from PPG 24, Annex 1)

noise source of concern is not present. This recognises that there may well be other existing sources which contribute to the ambient noise, but which are not under investigation.

The K factor is to account for the special characteristics of the noise, and is normally a +5 dB correction to be applied if one or more of the following features occur: distinctive impulses; whines; screeches; bangs; thumps; etc.

Background noise is normally defined as the noise level exceeded for 90% of the measurement period (L_{A90}).

BS 4142 states that if the difference between the rating level and the background is around +5 dB then it is of marginal significance. Complaints are likely if the difference is +10 dB.

Future planning

For some time, it has been possible to use computers to generate noise maps, using data based on the sound power output of industrial plant, and known traffic flow on roads, for instance. There are a number of these models in existence, some of which have been included into international standards, such as ISO 9613. These models calculate all the paths from source to receiver. Sound waves are attenuated by obstructions, reflections from absorptive surfaces such as open ground, and by the atmosphere. The amount of attenuation with distance can also be altered significantly by the wind direction and by temperature gradients.

Airports have also used standard calculation methods based on aircraft noise data and timetabling information to plot noise contours on the ground. Any observed differences have been difficult to blame on any particular aircraft. However improved technology is now available in the form of permanent monitoring systems. Noise measurement terminals are situated in the community, constantly monitoring the noise levels, and synchronised to the radar tags which the aircraft use to identify themselves to air traffic control. It is possible therefore to identify if an individual aircraft has deviated from an agreed navigation corridor, or is causing excessive noise.

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relates to the assessment and management of environmental noise. This is a major attempt to harmonise noise prediction methods, and to develop new noise indicators which reflect the noise impact on the population, and which can be incorporated into a common assessment policy.

With a significant amount of effort now being applied to noise regulation, noise labelling based on sound power and low noise design it would be reasonable to expect that the impact of unwanted noise on our lives would be in decline. However utopian this may appear, it is also clear that it will be some time before the requirement to undertake noise impact assessments is removed. ■

Acknowledgements

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