Health impacts of aircraft noise – briefing for the DfT aviation policy scoping consultation

1. Policy

The White Paper "The Future of Air Transport" (ATWP, para 3.32) made the following commitments in respect of the health impacts of aviation:

"The public health impacts of aviation are a matter which the Government takes very seriously . . . . . Research continues on the effects of noise on human health, and the Government will take account of existing guidelines from the World Health Organisation. We are also supporting research to obtain better evidence on this and, through the European Commission, on whether, for example, aircraft noise exposure in schools can interfere with children's cognitive performance."

and, when making planning applications (ATWP, para 12.2):

"Airport operators will . . . be expected to undertake appropriate health impact assessments."

The current scoping document refers to health effects of noise as follows (para 4.11):

"The Noise Policy Statement for England (NPSE[1]) contains a high-level vision of promoting good health and good quality of life through the effective management of noise in the context of Government policy on sustainable development. It is supported by three aims, including avoiding significant adverse impacts on health and quality of life. Comparable principles apply for other parts of the UK."

The NPSE is a very brief document which sets out the Government's noise policy aims as:

"Through the effective management and control of environmental, neighbour and neighbourhood noise within the context of Government policy on sustainable development:

- avoid significant adverse impacts on health and quality of life;
- mitigate and minimise adverse impacts on health and quality of life; and
- where possible, contribute to the improvement of health and quality of life."

While the explanatory note accompanying the NPSE acknowledges the World Health Organisation's definition of health as "as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", it states that "in the NPSE it has been decided to make a distinction between 'quality of life' which is a subjective measure that refers to people's emotional, social and physical well being and 'health' which refers to physical and mental well being". It appears to place sleep disturbance and annoyance under the 'quality of life' heading while acknowledging that "there is emerging evidence that long term exposure to some types of transport noise can additionally cause an increased risk of direct health effects".

2. Evidence of impacts and exposure

In 1991, the World Health Organisation (WHO) published *Guidelines for Community Noise* based on extensive scientific literature. Since then and the publication of the White Paper in 2003, a very significant volume of research on the impacts of environmental noise on human health has been

[1] *Noise Policy Statement for England*, Department for Environment, Food & Rural Affairs, March 2010

published and maps showing exposure to noise have been produced by European countries in response to EC Directive 2002/49/EC.

The WHO based its *Night Noise Guidelines for Europe* (2009) on this wide-ranging research base and, in 2011, it published its assessment of the *Burden of disease from environmental noise* combining the evidence for health impacts with the exposure data from noise mapping.

In the following sections, I have summarised these documents and gathered information on noise limits for aviation which apply in the UK and other European countries.

3. The burden of disease from aircraft noise in the UK

In 2011, the WHO published a report[2] which estimated the number of healthy life years lost annually to environmental noise in Europe. The health impairments assessed were cardiovascular disease, cognitive impairments in children, sleep disturbance, tinnitus and annoyance.

The unit of disability adjusted life-years (DALYs) employed combines actual years lost through deaths from disease with person-years lived with disability. The latter employs a weight factor between 0 and 1 for the degree of disability, 1 indicating death.

Where possible, the impact of noise was calculated using dose-response relationships derived from meta-analyses of extensive epidemiological studies. For aircraft noise, useful models could be produced only for sleep disturbance and annoyance although there is also useful evidence of a noise threshold above which the risk of hypertension is raised.

The study applied these models to noise exposure data from the noise mapping exercise carried out across Europe to comply with the European Noise Directive (END)[3].

Its central conclusion for aircraft noise is that, across Europe, nearly 60,000 DALYs are lost annually by highly sleep-disturbed individuals and over 100,000 DALYs by highly annoyed people.

I have applied the dose-response models to the UK noise mapping exposure data for airports (see Appendix 1) and conclude that, in populations around airports where :

- Over 3,300 disability adjusted life-years (DALYs) are lost annually by highly sleep-disturbed people living with noise levels above 45 dBA L_{night}
- High levels of annoyance result in the loss of over 3,500 disability adjusted life-years (DALYs) each year by individuals living with noise levels above 55 dBA L_{den}

In addition, the exposure estimate method used by the WHO suggests that nearly 19,000 additional DALYs are lost annually by people living in towns of over 50,000 population and who are highly annoyed by aircraft noise while exposed to noise levels below 55 dBA L_{den}.

The WHO report also presents data on susceptibility to raised blood pressure (hypertension) arising from exposure to aircraft noise which suggests that noise levels greater than 55 dBA L_{den} are

[2] *Burden of disease from environmental noise*, World Health Organisation, 2011
[3] Directive 2002/49/EC, June 2002

associated with a enhanced risk of hypertension. The noise maps for 2006 showed that over a million people around UK airports experienced noise above this level.

4. Noise guidelines and limits

4.1. WHO Guidelines for Community Noise 1999

The WHO guidelines published in 1999 considered a wide range of impacts of community noise on health. In dwellings, the typical effects were considered to be sleep disturbance, annoyance and speech interference.

During the daytime and evening, for the avoidance of serious annoyance from continuous noise in outdoor areas a limit of 55 dBA $L_{eq,\ 16hr}$ is recommended (note that these guidelines predate the adoption of the L_{den} and L_{night} metrics). To avoid moderate annoyance and degraded intelligibility of speech inside dwellings, an outdoor limit of 50 dBA $L_{eq,\ 16hr}$ is recommended.

To avoid sleep disturbance and allow sleeping with open windows, it is recommended that outside noise measured at 1 metre from the building façade should not exceed 45 dBA $L_{eq,\ 8hr}$ and 60 dBA $L_{Amax,FAST}$. Note that the document states that:

"A noise measure based only on energy summation and expressed as the conventional equivalent measure, LAeq, is not enough to characterise most noise environments. It is equally important to measure the maximum values of noise fluctuations, preferably combined with a measure of the number of noise events."

It also notes that: "When prominent low-frequency components are present, noise measures based on A-weighting are inappropriate."

4.2. WHO Night Noise Guidelines for Europe 2009

Based upon a large volume of studies which had accumulated since the 1999 guidelines were published, in 2009 the WHO Regional Office for Europe published guideline values of night noise exposure to prevent harmful effects of night noise in Europe. It identified a number of noise thresholds for the onset of health impacts which are presented in Appendix 2 along with its summary of observed health effects at different levels of $L_{night,outside}$.

Based on this evidence, the WHO recommends that:

"For the primary prevention of subclinical adverse health effects related to night noise in the population, it is recommended that the population should not be exposed to night noise levels greater than 40 dB of $L_{night,outside}$ during the part of the night when most people are in bed. The LOAEL [see (e) below] of night noise, 40 dB $L_{night,outside}$, can be considered a health-based limit value of the night noise guidelines (NNG) necessary to protect the public, including most of the vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise.

"An interim target (IT) of 55 dB $L_{night,outside}$ is recommended in the situations where the achievement of NNG is not feasible in the short run for various reasons. It should be emphasized that IT is not a health-based limit value by itself. Vulnerable groups cannot be protected at this

level. Therefore, IT should be considered only as a feasibility-based intermediate target which can be temporarily considered by policy-makers for exceptional local situations."

The following important points should be borne in mind when interpreting the recommendations:

a) The recommendations are derived from review of available information from the medical and other literature. Around 500 references are cited. Much of the data has become available since the WHO Guidelines for Community Noise (1999) were published. Field data on noise exposure has, in the main, been culled from studies of road and aircraft noise.

b) The $L_{night,outside}$ noise indicator was chosen as the basis of the guidelines as it is mandated in the Environmental Noise Directive (END, 2002/49/EC, 2002) in response to which the Noise Maps and Noise Action Plans were produced. It is an "average noise" indicator which, while it may be suitable for some health effects such as those impacting the cardiovascular and nervous systems, may not be a good predictor for sleep disruption which is likely to depend upon the magnitude and number of noise events experienced. To convert event-based indicators to $L_{night,outside}$ for disturbance by aircraft, the WHO assumed that there are 8 events per night.

c) $L_{night,outside}$ indicates the average noise level experienced during the 8 hours of the night, usually 23:00 to 07:00, over a whole year, usually a calendar year. The report references studies in the Netherlands and Portugal which demonstrate that, because there are wide variations in both sleeping time and the beginning and end times of sleep, an 8-hour period is adequate to protect the full sleeping time of only half of the population. A period of 10 hours would be needed to protect 80 per cent. This has important implications for airport night noise controls which often regulate night flying in time periods as short as 6.5 hours.

d) Because $L_{night,outside}$ is a full-year indicator, indoor noise levels have been assumed to be 21 dB below outdoor levels. This compares with the figure in the WHO Guidelines for Community Noise (1999) of 15 dB which is based on windows being open at all times during the summer period which was usually used when calculating the L_{eq} indicators.

e) The study rejected basing the guidelines on the no adverse effect level (NOAEL) which is used in drug toxicology studies as the data available could not reliably indicate such a level. Instead, the night noise guideline (NNG) has been set at the low adverse effect level (LOAEL) above which it can be demonstrated that the health effects increase with increasing levels of noise.

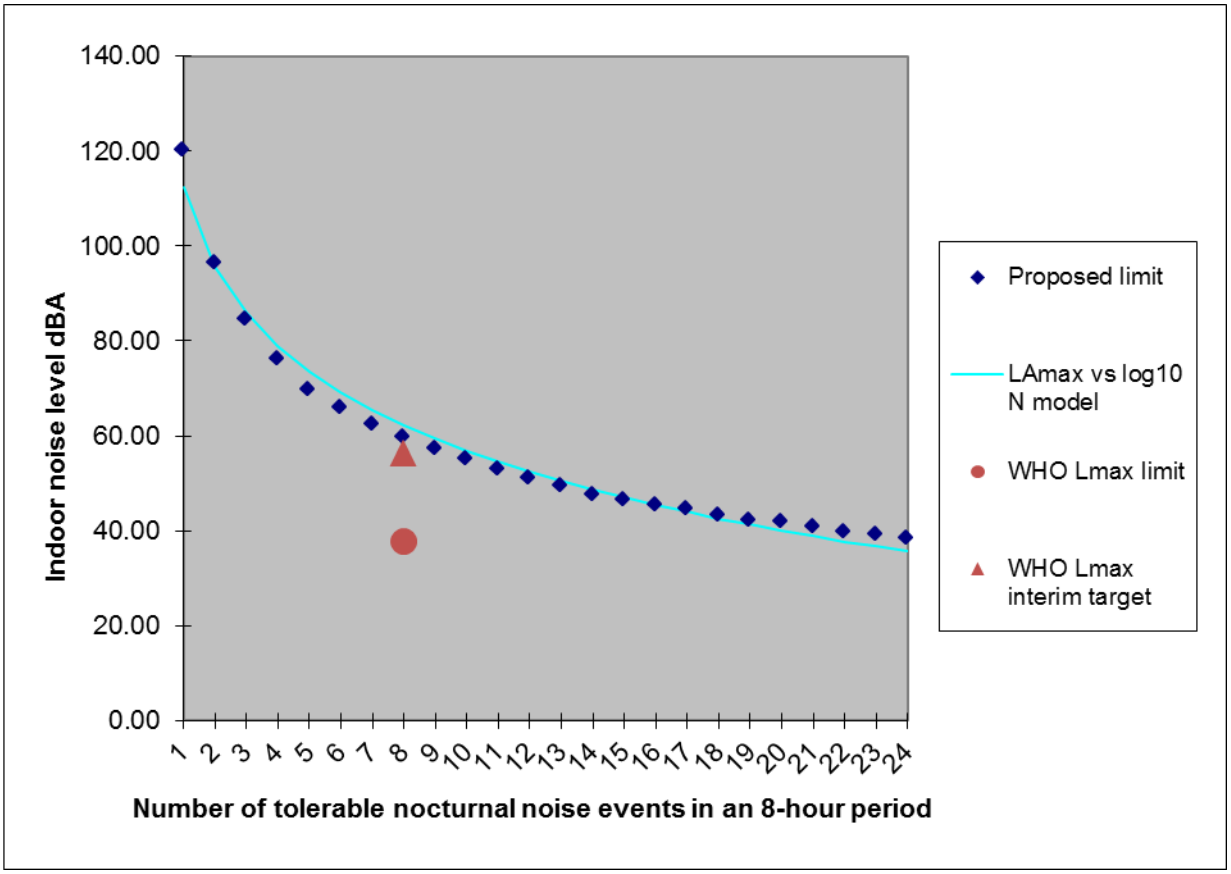
4.3. Awakenings caused by aircraft noise

As noted above, the expression of guidelines for sleep disturbance in terms of the L_{night} average noise indicator requires an assumption about the number of noise events which may not be valid. A paper published in 2004[4] explored the trade-off between maximum noise levels and the number of events to propose night noise limits. It based these on a model of admissible noise-

[4] Griefahn B, Scheuch K, Jansen G, Spreng M. Protection goals for residents in the vicinity of civil airports. Noise and Health 2004;6:51-62

induced release of cortisol[5] which produced a relation between noise and number which matched a similar relation giving rise to awakenings in a major study of aircraft noise effects.

The data transcribed from the reported relationship between recommended limiting combinations of noise and number is shown in the graph below.



The graph also shows the equivalent WHO night noise limits transcribed to maximum indoor levels.

I carried out a regression analysis to establish the relationship between noise and the logarithm to base 10 of the number of noise events inherent in the proposed noise limits. Converting the L_{max} variable to L_{night} resulted in a relationship between L_{night} and the number of noise events in which a doubling of the number of events resulted in an approximately 10 dBA increase in L_{night}. This is an intuitively reasonable result as 10 dBA is equivalent to a doubling of loudness in human perception of noise and a far more realistic one than the 3 dBA inherent in L_{eq}-based metrics.

4.4. **Aircraft Noise limits in Europe**

The Noise Observation Service for Europe (NOISE) maintains a web site[6] which presents data reported by European Union member states and member countries of the European Environment Agency in accordance with European Noise Directive (END, 2002/49/EC) relating to

[5] Spreng M. (2002) Cortical excitation, cortisol excretion, and estimation of tolerable nightly over-flights. Noise and Health 4:39-46.
[6] noise.eionet.europa.eu

the assessment and management of environmental noise. The following table summarises the limit values in use in a number of countries reported by this web site in June 2011.

Country	Limit Values IN FORCE for aircraft noise around airports					
		Lden	Lnight	Lday	Levening	Comments
France		55 dB(A)	Not available	Not available	Not available	
Finland		55	50	Not available	Not available	Residential areas, recreational areas in built areas and areas in their proximity, and areas serving nursing or educational institutions
		45	40	Not available	Not available	Holiday settlements, camping sites, nature conservation areas
Hungary		63	55	Not available	Not available	
Latvia		Not available	40	50	45	For residential ares with detached houses, areas with hospitals, children and social care authorities as well as resort areas
		Not available	45	55	50	For residential ares, areas with culture, education, public administration and scientific authorities
		Not available	45	60	55	For areas with multifunctional buildings
		Not available	50	60	55	For business areas, areas with hotels, public authorities, sporting teritories as well as trading and services zones
Slovenia		*New noise sources*				*Level I. area: for areas that require increased protection against noise, i.e. nature areas devoted to turism and recreation, the immediate environs of hospitals, health resorts and rest homes, and areas in natural parks **Level II. Area: for areas where no intervention in the environment that is disturbing owing to the production of noise is permitted , i.e. areas whose primary purpose is residential or buildings with protected areas, solely residential areas, the environs of childcare, educational and primary healthcare facilities, playing fields, and public parks, public areas of greenery and public recreation grounds ***Level III. area: for areas where interventions that cause less disturbing noises are permitted, i.e. retail/business/residential areas that are designed for both residential purposes (or have buildings with protected areas) and small businesses and similar manufacturing activities (mixed areas), agricultural areas and public centres where administrative, retail, service and catering/entertainment activities take place ****Level IV. Area: for areas where interventions that cause more disturbing noise are permitted, i.e. non-residential areas designed for heavy or light industry or similar manufacturing processes, transport, warehousing or service activities, and noisy communal activities
	Level I. area*	Not available	37	47	Not available	
	Level II. Area**	Not available	42	52	Not available	
	Level III. area***	Not available	48	58	Not available	
	Level IV. Area****	Not available	68	68	Not available	
		Existing noise sources				
	Level I. area*	Not available	47	57	Not available	
	Level II. Area**	Not available	53	63	Not available	
	Level III. area***	Not available	59	69	Not available	
	Level IV. Area****	Not available	70	80	Not available	
The Netherlands		Not available	52-59	Not available	Not available	For aircraft noise around Schiphol airport, 35 "enforcement points" have been designated. At these points (located in residential areas in an approx 30 km radius around the airport), location specific limit values have been formulated ranging from 52.04 to 59.79 dB(A).
Slovakia		60	50	Not available	Not available	

It is not clear how these limit values are applied but, from the context and the use of the noise metrics mandated by the Directive, I assume that they were used for the noise mapping and subsequent noise action planning activities.

Some of the entries for the other 11 countries listed without limit values in the full data set have notes which refer to pre-existing noise criteria. An example is the UK's PPG24 guidelines for new development near airports.

Note that all of the countries reporting limits have limits in place for L_{night} and that, for residential areas, these are at or below the WHO Interim Target level, 55dBA.

5. **Conclusions and Recommendations**

In collating the information in this brief, it was my intention to enable discussion rather than propose a line of response to the scoping consultation. However, I cannot escape the conclusion that there is now very strong evidence of real health impacts of night noise from aviation and, with a number of European countries setting limits which, at least, comply with the WHO Interim Target, there can be no objection to adopting it as UK policy.

Of course, night noise can be mitigated more easily than daytime noise through insulation schemes but this makes it amenable to application for both development of and near to airports. However, where such mitigation is deployed, it will be important to stipulate that running as well as installation costs are underwritten by airport operators, particularly where active, energy-using active ventilation systems are required to achieve acceptable internal noise conditions.

Appendix 1: Healthy life years lost annually in the UK due to aircraft noise

In assessing the burden of disease from aircraft noise, the WHO used the numbers of people living in conurbations of 250,000 or larger who were subject to aircraft noise in different noise bands reported in the noise mapping exercise to derive the proportion s of population in the different noise bands. It then applied these to the numbers living in conurbations of 50,000 people or greater to estimate the numbers in Europe living in each band.

While this may produce credible exposure data for estimating the disease burden across Europe, it seemed to me that, as actual exposed population numbers are available from the UK mapping data, using this directly would produce a more realistic estimate for the UK. However, the mapping data does not provide the number of people exposed to aircraft noise at levels below 55 dBA L_{den} so this was estimated using the WHO approach which entailed subtracting the population exposed to noise above that level from the total population living in towns of greater than 50,000 (31,009,400 in 2008.

The WHO derived a range of weights for the various disabilities which it considered. It produced estimates based on a central estimate and two extremes. In the following tables showing the calculations for sleep disturbance and annoyance from aircraft noise, I have used all three weights employed by the WHO but, in accordance with the WHO's practice, I have confined reporting in the main text of this brief to the results from the central estimate. I have also reported the annoyance burden for people exposed to less than 55 dBA L_{den} separately as the WHO, without explanation, excluded this large group for aircraft noise when aggregating losses from all transport sources. I suspect this was an error.

DALYs lost for highly sleep-disturbed people due to air traffic noise in the UK

Exposure category Lnight	Population exposed 2006	Percentage of people highly sleep-disturbed		DALYs lost per annum		
			Disability weight	0.04	0.07	0.10
<45		N/A				
45-49	223,850	6.2		555.15	971.51	1,387.87
50-54	223,850	8.8		787.95	1,378.92	1,969.88
55-59	84,250	12.2		411.14	719.50	1,027.85
60-64	18,800	16.3		122.58	214.51	306.44
65-69	1,800	21.1		15.19	26.59	37.98
			Totals	1,892.01	**3,311.01**	4,730.02

The percentage disturbed w as calculated using the mid-level value of each exposure category.
Noise maps do not provide data for the categories of < 45 dB(A) and 45–49 dB(A) for Lnight. Therefore, the percentages of population in these categories w ere interpolated using a very conservative assumption: the percentage for the 45–49 dB(A) is the same as that for 50–54 dB(A) and that below 45 dB(A) w as assumed negligible.

DALYs lost for highly annoyed people due to air traffic noise in the UK

Exposure category Lden	Population exposed 2006	Percentage of people highly annoyed	Disability weight	DALYs lost per annum 0.01	0.02	0.12
<55	29,922,150	3.16		9,455.40	**18,910.80**	113,464.79
55-59	808,100	13.66		1,103.86	2,207.73	13,246.38
60-64	215,300	21.76		468.49	936.99	5,621.91
65-69	53,350	31.54		168.27	336.53	2,019.19
70-74	9,800	42.93		42.07	84.14	504.86
>75	700	42.93		3.01	6.01	36.06
		Totals above 55 dBA		1,785.70	**3,571.40**	21,428.40

The percentage annoyed was calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A)
As the exposure–response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed by the WHO to be the same as in the 70–74 dB(A) category.

Appendix 2: Thresholds for night noise health impacts and summary of observed effects

Effect	Indicator	Threshold, dB
Effects where *sufficient* evidence is available:		
EEG awakening	$L_{Amax,inside}$	35
Motility, onset of motility	$L_{Amax,inside}$	32
Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep	$L_{Amax,inside}$	35
Waking up in the night and/or too early in the morning	$L_{Amax,inside}$	42
Increased average motility when sleeping	$L_{night,outside}$	42
Self-reported sleep disturbance and diagnosed environmental insomnia	$L_{night,outside}$	42
Use of somnifacient drugs and sedatives	$L_{night,outside}$	40
Effects where *limited* evidence is available:		
Complaints	$L_{night,outside}$	35
Hypertension	$L_{night,outside}$	50
Myocardial infarction	$L_{night,outside}$	50
Psychic disorders	$L_{night,outside}$	60

Although the following effects have been shown to occur or a plausible biological pathway could be constructed for them, indicators for threshold levels could not be determined:

- Change in cardiovascular activity
- Prolongation of the sleep inception period, difficulty getting to sleep
- Sleep fragmentation, reduced sleeping time
- Changes in (stress) hormone levels
- Drowsiness/tiredness during the day and evening
- Increased daytime irritability
- Impaired social contacts
- Impaired cognitive performance
- Medical conditions Insomnia
- Obesity

- Depression (in women)
- Reduction in life expectancy
- (premature mortality)
- (Occupational) accidents

The document summarises the observed effects of environmental noise at night as follows:

Average night noise level over a year $L_{night,outside}$	**Health effects observed in the population**
Up to 30 dB	Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the no observed effect level (NOEL) for night noise.
30 to 40 dB	A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise.
40 to 55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
Above 55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.