New recommendations from WHO to limit annoyance from aircraft noise is not supported by existing evidence

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ABSTRACT

The European Region of the World Health Organization recently published revised recommendations for transportation noise exposure intended to limit adverse health effects. WHO's newly recommended "safe" limit for aircraft noise exposure is about an order of magnitude lower than the limits currently adopted by most European countries. WHO defines "safe exposure" as the level corresponding to an annoyance prevalence rate of 10 % highly annoyed.

The revised recommendations are based on a rather limited selection of post-2000 publications. About half of the cited studies rely on nonstandard questionnaires, respondent selection, and definitions of annoyance prevalence rates which over-estimate annoyance. A re-analysis of a larger and more representative selection of studies that rely on standard procedures shows that no meaningful changes in prevalence rates of high annoyance with aircraft noise have occurred, and that existing evidence does not support WHO's revised recommendations.

INTRODUCTION

The European Region of the World Health Organization, WHO, recently published revised recommendations for transportation noise exposure intended to limit adverse health effects [1]. Guski, Schreckenberg and Schümer were commissioned by WHO to collect and analyze findings of recent surveys on aircraft noise annoyance [2]. Guski *et al.* identified 15 aircraft noise annoyance surveys conducted from 2001 to 2014. They rejected three of these surveys for various reasons and compiled a database comprised of twelve surveys with a total of 17 094 respondents. The respondents to half of these surveys were participants in the HYENA study [3] which had been designed primarily to study hypertension among people living in airport-vicinity residential neighborhoods. The design of the HYENA study did not therefore follow standard recommendations as specified in ISO/TS 15666 [4].

Guski *et al.* used a multi-step analysis method to derive a common exposure-response function ("ERF") for these surveys. First the original data from each individual survey, percentage highly annoyed vs. average noise exposure level (DNL or DENL), was plotted in a scatter diagram and a polynomial regression function was fitted to each dataset. These regression equations were used to calculate a predicted percentage of highly annoyed at discrete exposure levels for each survey. Finally, a quadratic regression function was fitted to the "estimated data points" that weighted the findings of each survey in proportion to the number of participants in each study. Figure 1 summarizes the findings of Guski *et al.* The current study applies the analysis methods of Guski *et al.* to various supersets of aircraft noise survey findings.

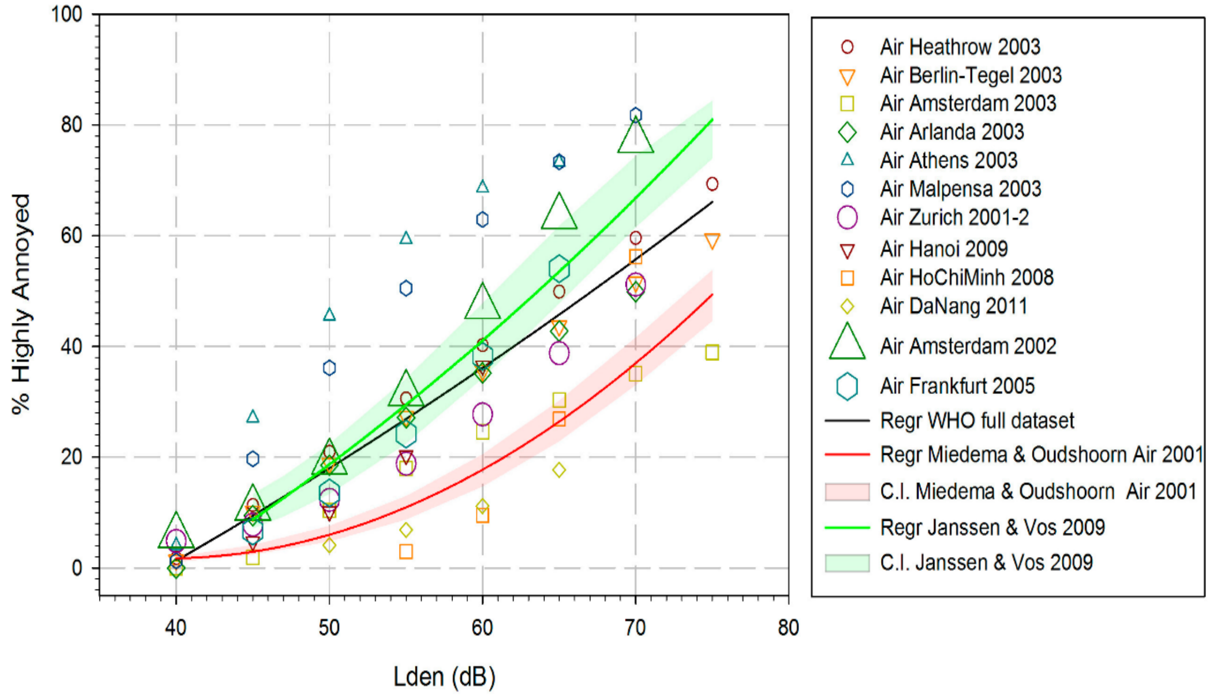

Figure 1. The average exposure-response function (solid black line) for 12 surveys on aircraft noise annoyance (WHO full dataset) conducted between 2001 and 2011 [2].

METHOD

Numerous social surveys have been conducted over the past five decades to establish the relationship between noise exposure and prevalence of high annoyance. Sixty-five surveys on aircraft noise annoyance conducted between 1961 and 2015 were identified for which sufficient information is available to calculate ERFs for individual studies, see Table 1. Surveys included in this analysis have noise data that could be converted to DNL or DENL, and the response has been reported as prevalence of high annoyance defined as the upper 25 – 30 percent of the annoyance scale. No distinction has been made in this paper between the two noise indices L_{den} and L_{dn}, as the difference between them is less than 0.5 dB [5]. The complete dataset contains annoyance data and noise exposure levels for more than 93,000 respondents from Europe, North America, Australia, and Asia.

Table 1. Aircraft noise surveys included in the present analysis

year	code	survey site	respond	ref.
1961	UKD-008	First Heathrow (McKennell)	1724	A1, A2
1965	FRA-016	Four French airports (Alexandre)	2000	A3, A2
1967	UKD-024	Second Heathrow	4699	A4, A2
1967	USA-022	Four US airports – Tracor phase 1 (Connor *et al.*)	3590	A5, A2
1967	USA-032	Three US airports – Tracor phase 2 (Connor *et al.*)	2912	A5, A2
1969	GER-034	Munich airport (Deutsche Forschungsgemeinschaft))	660	A6, A2
1970	USA-044	Two US small city airports – Tracor (Connor *et al.*)	1960	A5, A2
1971	SWI-053	Three Swiss airports (Grandjean et al.)	3939	A7, A2
1972	SWE-035	Nine Scandinavian airports (Rylander *et al.*)	3746	A2
1973	USA-082	LAX Airport (Fidell *et al.*)	452	A8
1978	CAN-168	Four Canadian airports (Hall *et al.*)	673	A9, A2
1979	USA-203	Burbank airport (Fidell et al.)	924	A2
1980	AUL-210	Five Australian airports (Bullen and Hede)	3575	A10, A2
1980	BEL-288	Brussels airport (Jonckheere)	677	A11

1981	USA-338	Seven US air force base (Borsky *et al.*)	942	A12
1981	USA-204	John Wayne – Orange County airport (Fidell *et al.*)	3103	A2
1982	USA-301	Westchester airport (Fidell *et al.*)	1465	A13, A2
1982	USA-250	Decatur airport (Schomer *et al.)*	234	A14, A2
1983		Pittsburg airport (Fidell *et al.*)	140	A15
1984	FRA-239	French combined aircraft/road (Vallet *et al.*)	1030	A16
1984	UKD-238	Glasgow airport (Atkinson *et al.*)	608	A16
1984	NET-240	Amsterdam airport (Miedema *et al.*)	1046	A16
1985	UKD-243	UK ANIS (Atkins *et al.*)	2173	A17
1987	GER-373	Two German airports (Kastka *et al.*)	516	A18
1988	SWE-419	Three Swedish airports (Rylander *et al.*)	513	A19
1989	NOR-311	Oslo-Fornebu airport (Gjestland *et al.*)	3354	A20
1989		Long Beach airport (Fidell *et al.*)	2505	A21
1990	NOR-366	Trondheim-Værnes airport (Gjestland *et al.*)	1195	A22
1991	USA-349	Atlanta airport (Fidell *et al.*)	922	A23
1991		Zurich and Geneva airports (Oliva *et al.*)		A24
1992	NOR-328	Bodø airport (Gjestland *et al.*)	3267	A22
1995	CAN-385	Vancouver round 1 (Fidell *et al.*)	1067	A25
1995	USA-431	Seattle-Tacoma airport (Fidell *et al.*)	2472	A26
1996	JPN-491	Osaka airport (Yamada *et al.*)	215	A27
1996	USA-428	Minneapolis-St.Paul airport (Fidell *et al.*)	2679	A28
1996	GES-1	Amsterdam airport (Breugelmans *et al.*)		A29
1996		Birmingham airport (Whitfield *et al.*)	1072	A30
1997	USA-432	El Segundo (Fidell *et al.*)	644	A31
1998	FRA-395	Orly/Roissy airports (Vallet *et al.*)	1334	A32
1998		Vancouver round 2 (Fidell *et al.*)	1000	A33
1998		Frankfurt airport (Kastka *et al.*)	1147	A34
1998		Munich airport (Kastka *et al.*)	1050	A35
1999		South San Francisco airport (Fidell *et al.*)	1250	A36
2001	SWI-525	Zurich airport (Brink *et al.*)	1520	A37
2002		Richfield airport (Fidell *et al.*)	495	A38
2002	GES-2	Amsterdam airport (Breugelmans *et al.*)	640	A39
2003	SWI-534	Zurich airport (Brink *et al.*)	1444	A37
2004	KOR-554	Two Korean airports (Lim *et al.)*	720	A40
2005		Frankfurt airport (Schreckenberg *et al.*)	2309	A41
2005		Cincinnati airport (Fidell *et al.*)	1606	A42
2005	UKD-604	Ten UK airports - ANASE (Le Masurier)	2132	A43
2005	GES-3	Amsterdam airport (Breugelmans *et al.*)	640	A39
2008		Ho Chi Minh (Nguyen *et al.*)	880	A44
2009		Hanoi Noi Bai airport (Nguyen *et al.*)	824	A44
2010		Cologne/Bonn airport (Bartels)	1262	A45
2011		Da Nang airport (Nguyen *et al.*)	528	A46
2014		Bodø airport (Gelderblom *et al.*)	302	A47
2014		Trondheim-Værnes airport (Gelderblom *et al.*)	300	A47
2014		Oslo-Gardermoen airport (Gelderblom *et al.*)	300	A47
2014		Stavanger airport (Gelderblom *et al.*)	302	A47
2014		Tromsø (Gelderblom *et al.*)	300	A47
2014		Hanoi Noi Bai airport (Nguyen *et al*)	910	A48
2014		Hanoi Noi Bai airport (Nguyen *et al.*)	1121	A48
2014		Nine UK airports - SoNA	1847	A49
2014		Swiss noise study (Brink *et al.*)	3097	A50

RESULTS

Figure 2 shows the resultant average exposure-response function for all 65 surveys identified above.

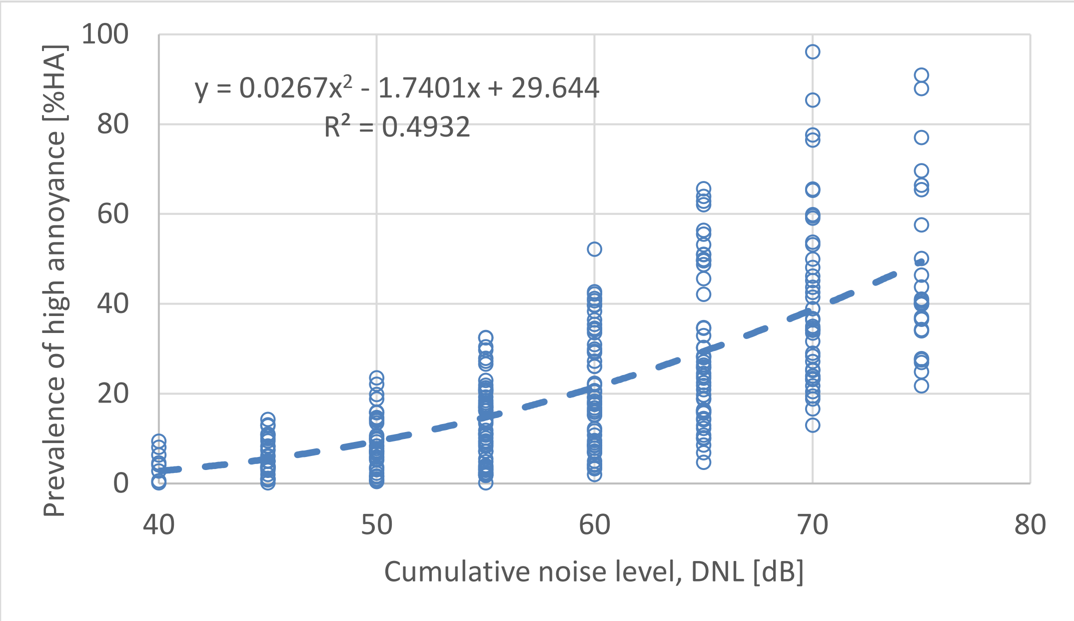

Figure 2. Scatterplot and quadratic regression of the relation between L_{dn} and the predicted/calculated percentage highly annoyed for 65 surveys conducted between 1961 and 2015.

The quality of noise exposure estimates for older surveys has sometimes been questioned since measurement and noise modeling techniques have greatly improved in recent decades. For comparative purposes the Guski *et al.* analysis procedure has been applied to 22 surveys conducted after 2000. The results are shown in Figure 3.

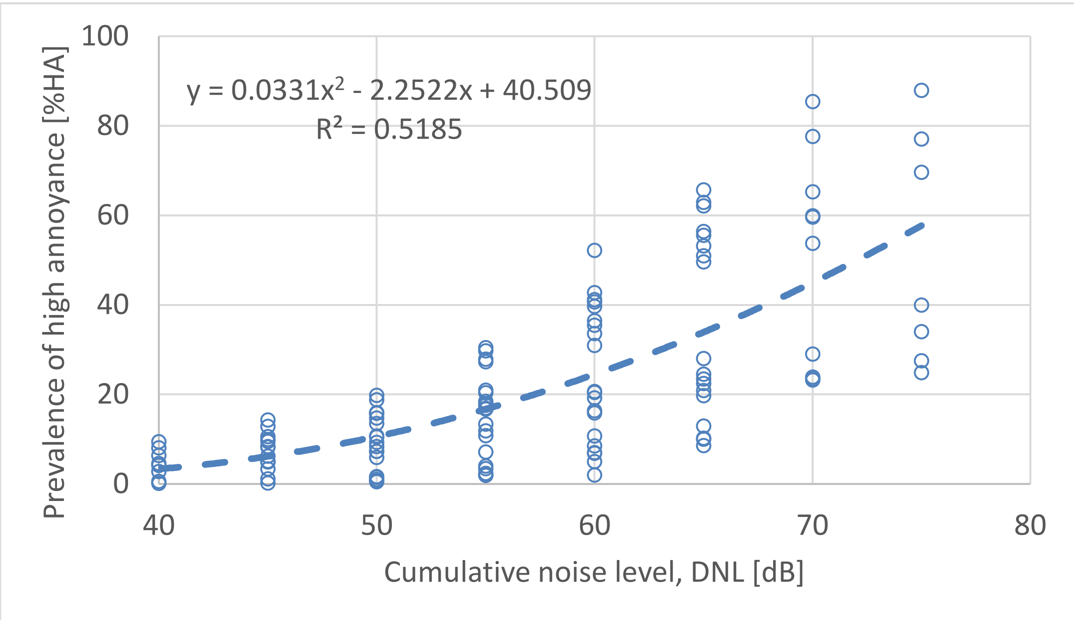

Figure 3. Scatterplot and quadratic regression of the relation between L_{dn} and the predicted/calculated percentage highly annoyed for 22 surveys conducted between 2001 and 2015

TEMPORAL TRENDS

As Figures 2 and 3 show, annoyance prevalence rates observed in different studies vary considerably. At a noise exposure level of L_{dn} = 60 dB, the predicted prevalence of high annoyance varies from about zero to 55 % HA. Likewise, the prevalence rate of 10 % highly annoyed can be found for exposure levels ranging from below 45 dB to 65 dB. The variability is very likely due to non-acoustic factors, of which one prominent factor could be a temporal trend. In other words, it is sometimes hypothesized [2] that people's reactions to noise have changed over time.

One way to study a hypothetical temporal shift in sensitivity to noise exposure is to calculate for each individual survey the noise level at which a certain percentage of the population is highly annoyed, and then plot these results as a function of the year of conduct of each survey.

The cumulative noise exposure associated with a 10 percent prevalence rate of high annoyance has been plotted as a function of survey year in Figure 4. Three linear regression lines have been fitted to the data representing the periods 1961-2015, 1980-2015 and 2000 - 2015.

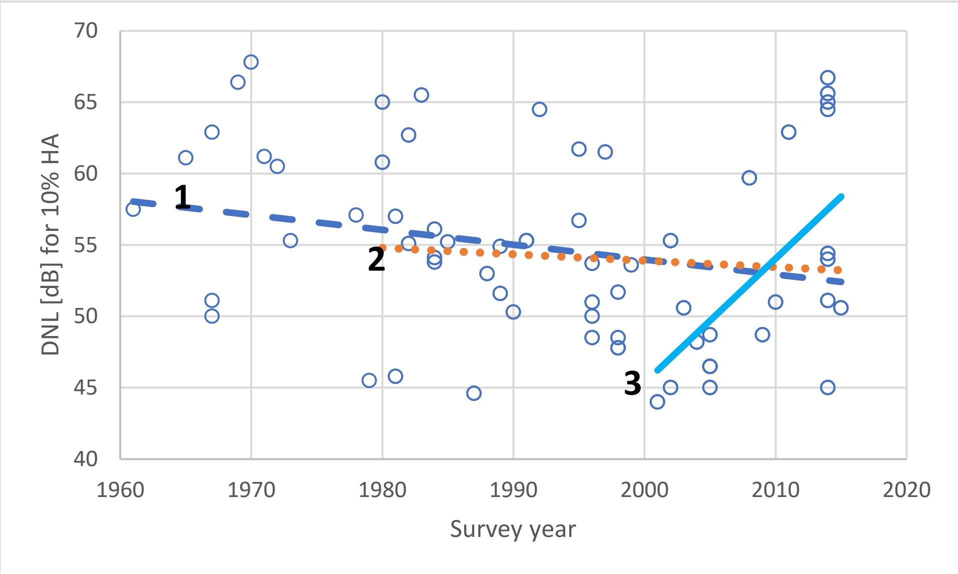

Figure 4. Scatterplot and regressions for the relation between study year and noise level associated with a 10 % high annoyance rate. Linear regression lines are shown for 1) the whole period 1961-2015 (dashed line); for 2) 1980 – 2015 (dotted line); and for 3) 2000 – 2015 (solid line).

DISCUSSION

The result of an analysis based on statistical regression methods is an artifact of the analysis method. As used by Guski *et al.,* a quadratic regression function, has a minimum (or maximum) value which often appears within the exposure range of interest. This contradicts the assumption (and observation) that the prevalence of high annoyance increases monotonically with noise exposure. Analysts often make adjustments, especially at the low end of the regression curve, to compensate for this inconvenience. One adjustment could be to fix the value of the regression function in some points based on the observation data. Some researchers favor different regression functions to avoid the maximum-minimum issue, for instance a logistic function that approaches the extremea asymptotically. Miedema and

Vos [6], for example, when developing the ERF which is currently being used by the EU, forced their quadratic regression function to zero at L_{dn} = 42 dB based on their observation of actual response data. This is illustrated in Figure 5.

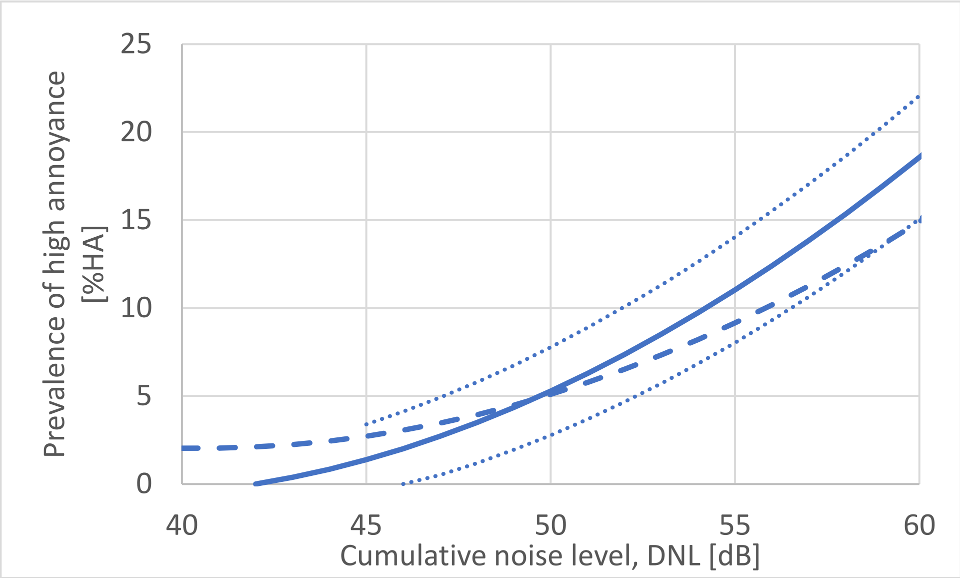

Figure 5. The lower end of the EU reference curve for aircraft noise annoyance (solid line) with corresponding 95 % confidence intervals (dotted lines). A similar ERF is shown for the Miedema & Vos dataset with the method used by Guski *et al.* (dashed line).

The ERF developed by Miedema and Vos is based on 20 surveys conducted between 1965 and 1992 containing annoyance judgments of about 34,000 respondents. The analysis method used by Guski *et al.* was applied to the same 20 survey dataset. Guski *et al.* did not do any corrections/adjustments at the low end of their regression function. As can be seen in Figure 5 the ERF calculated using the method devised by Guski *et al.* over-estimates the annoyance prevalence rate at low exposure levels compared with the EU curve.

Figure 6 shows the lower part of the exposure-response functions calculated from the entire dataset and from the 23 post-2000 surveys. No confidence intervals have been calculated for these ERFs. However, a visual comparison with the Miedema and Vos ERF ("the EU reference curve") with its flanking 95 % confidence limits confirms that the two new ERFs are not meaningfully different. This is especially true at the lower part of the exposure range, which is most important for regulatory purposes. It may therefore be concluded that, contrary to the findings of Guski *et al*., the prevalence of high annoyance with aircraft noise has not meaningfully changed over the last half century.

The analysis of temporal change in the annoyance response suggests a decrease in tolerance for aircraft noise exposure equivalent to about 6 dB from 1960 to 2015. In other words, Figure 4 suggests that people today will tolerate 6 dB less noise than they did 55 years ago for the same proportion of high annoyance. If the time frame is limited to 35 years, 1980 – 2015, the temporal change is only about 1.5 dB. However, by looking at the period from 2000 and onward there seems to be a large increase in people's tolerance to noise. According to the data in Figure 4 people today on average tolerate 13 dB higher noise levels than they did in 2000. These results simply demonstrate that any attempt to develop average exposure-response functions is critically dependent on the selection of surveys.

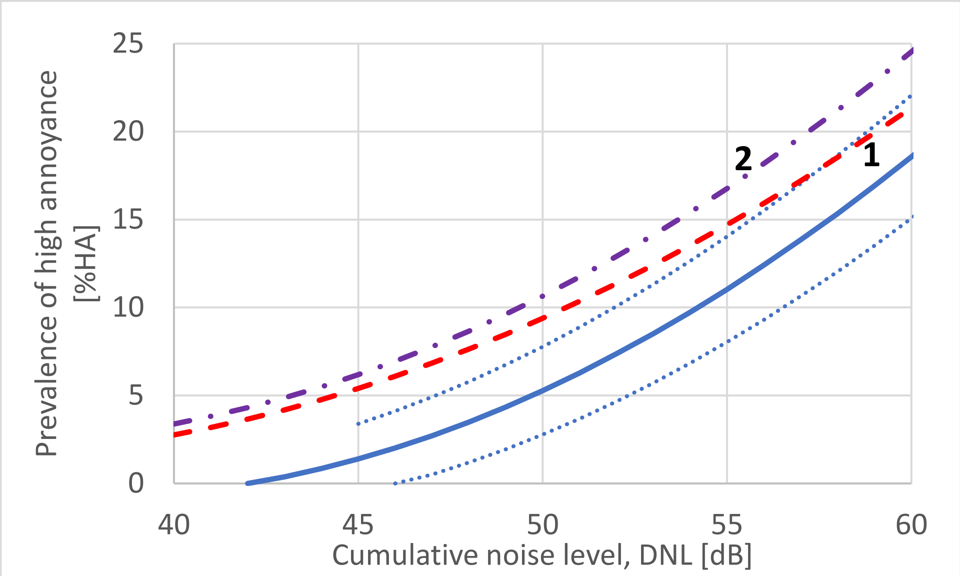

Figure 6. Exposure-response functions for aircraft noise calculated using the described regression method (see text). ERFs based on 1) 65 surveys conducted between 1961 and 2015 (dashed line) and on 2) 23 post-2000 surveys (dash-dotted line). The solid line is the current EU reference curve with its flanking 95 % confidence limits.

The World Health Organization has recently recommended that exposure to aircraft noise be limited to L_{dn} = 45 dB to prevent adverse health effect. This limit corresponds to a prevalence rate of 10 % highly annoyed. WHO's recommendation is based on a limited selection of 12 surveys and about 17,000 respondents.

Figure 6 indicates that a limit L_{dn} = 45 dB is unreasonably low. The two ERFs in this figure are based on 1) 65 surveys with about 93,000 respondents, and 2) 23 recent surveys conducted after year 2000 with about 24,000 respondents respectively. Figure 4 shows that a prevalence rate of 10 % highly annoyed has been found at an exposure level $L_{dn} \leq 45$ dB in only five out of 65 surveys.

Bearing in mind that the idiosyncratic analysis method used by Guski *et al.* over-estimates the annoyance response at low noise levels, the recommended limit should not be below L_{dn} = 50 dB. Since no temporal change in the annoyance response has been found, the detailed analysis by Miedema and Vos can still be considered the best estimate for prevalence of annoyance with aircraft noise [7]. According to their exposure-response curve an annoyance prevalence rate of 10 % HA corresponding to the limit to avoid adverse health effects should be set at L_{dn} = 54 dB, not 45 dB, as recommended by WHO.

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