ORIGINS AND APPLICATION OF THE EU POSITION PAPER ON DOSE RESPONSE RELATIONSHIPS BETWEEN TRANSPORTATION NOISE AND ANNOYANCE

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1. INTRODUCTION

This paper explains the context in which the European Commission developed a Position Paper which recommends the form of dose-response relationships linking noise exposure in Lden to percentage of persons indicating various degrees of annoyance. The substance of the EU paper is reproduced for the benefit of those not attending the conference. Finally some observations are made on related future developments.

2. CONTEXT

In 1998, on the occasion of the Copenhagen conference, the European Commission created an EU noise Expert Network, whose mission was to provide assistance in the development of the European noise policy. In particular this assistance was directed towards the Directive on the Assessment and Management of Environmental Noise [DAMEN].

A noise steering group was established, comprising representatives of all the interested stakeholders – Member States, local authorities, industry, NGOs.
In order to provide guidance, a set of working groups was also established. Initially, five working groups were set up dealing with the perception and transmission related aspects, three were dealing with sources of noise (road, rail and outdoor equipment), and two more working groups were responsible for noise research and for costs and benefits of noise abatement policies. Figure 1 sets out this original structure.

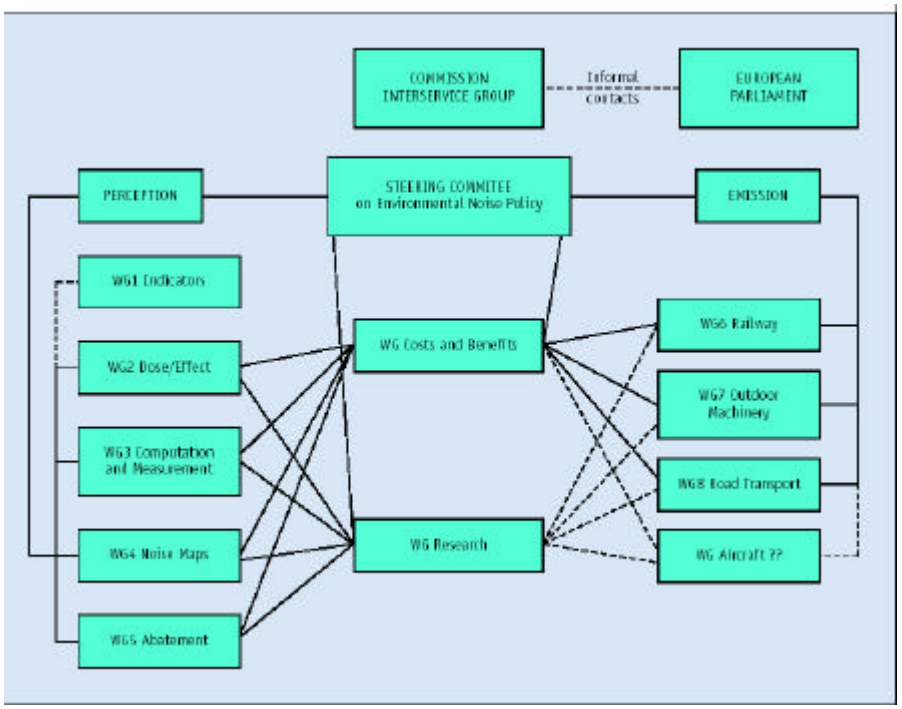
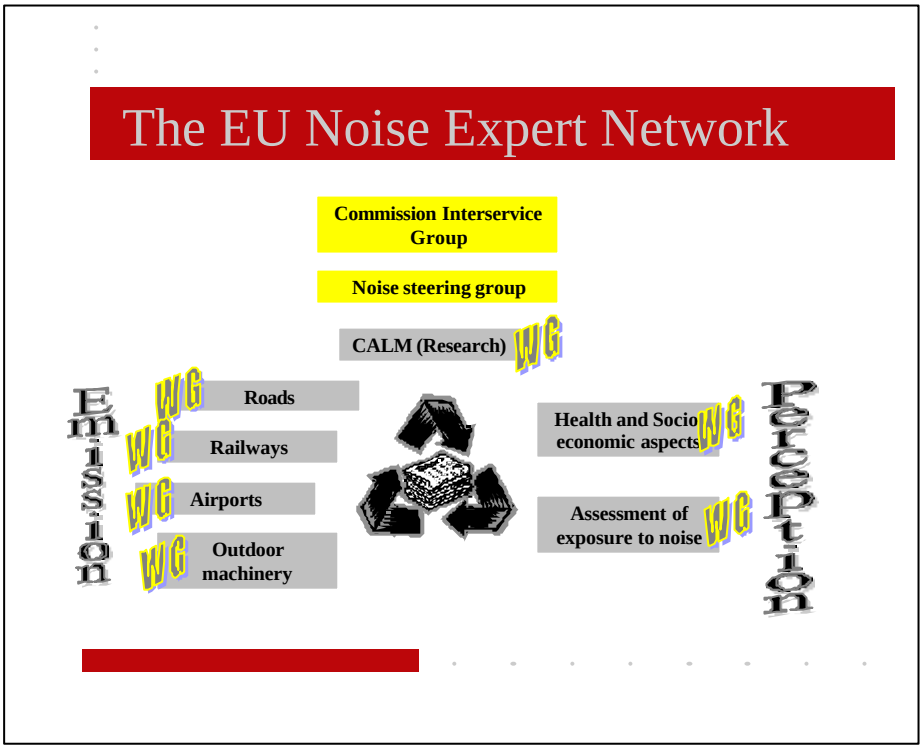


Figure 1. Original EU Working Groups 1998.

The Steering group and its associated working groups assisted the Commission in the development of its July 2000 proposal for an Environmental Noise Directive [1]. In particular, Working Group 1 produced a Position Paper on EU Noise Indicators [2] which provided a useful basis for the choice of common noise indicators to be used throughout Europe for the assessment of environmental noise.
Meanwhile Working Group 2 “Dose-Effect” considered a whole range of potential health effects but, based on consideration of reviews such as those published by the WHO [3], by the Health Council of the Netherlands [4], and by Porter, Flindell and Berry [5], they decided Annoyance and Sleep disturbance were the most prevalent and sensitive effects, and those for which the best data were available. Therefore the first priority was to develop a Paper to provide guidance on the dose-effect relations to be used for the assessment of numbers of people annoyed by noise from transportation sources (rail, road and air). This work had reached an advanced stage when the Commission decided, early in 2001, to reshape the EU noise expert network. The aim was to streamline its work and ensure a better co-ordination between the actual needs of the different stakeholders and the work undertaken by the network. To this end, it was decided with the support of the Noise Steering Group to create a working group dedicated to airport noise, and to merge the former working groups dedicated to perception and the working group on costs and benefits into two working groups, namely:

Working group "Health and socio-economic aspects" or WG HSEA (merger of former working groups on "dose & effect relations", "abatement" and "costs and benefits") and
Working group "Assessment of exposure to noise" or WG AEN (merger of former working groups on "noise mapping" and "computation and measurement methods")

The new structure is shown in Figure 2, and is described in detail on the EU noise policy website.
http://europa.eu.int/comm/environment/noise/home.htm



Because of the re-structuring, there were considerable delays in the process of publishing the Position Paper. It was finally published on the EU website
a few months ago, and dated as February 2002. Annex 2 of the paper – see below – provides more of the background context as it outlines the key meetings of WG2 during the development of the Paper.

3. THE POSITION PAPER

Copies of the complete Position Paper will be available at the Conference. For convenience of those not attending, the essential main text of the paper is reproduced here. However the complete paper, including the TNO publications [6,7] containing the detailed technical explanation is available on the EU website, and should be consulted.

----------**extract**----------

I - Introduction

Working Group 2 Dose/Effect was formed in 1998 by the European Commission with the following scope: *The WG shall support the European Commission with the development of the dose-effect relations for the proposed framework directive on the Assessment and Management of Environmental Noise.*

The present Position Paper[1] is one in a series on different topics within that scope that will be produced by the working groups assisting the European Commission in the coming years. After a series of meetings, one of the members of the WG, Dr Henk Miedema of TNO in the Netherlands, was contracted by the Commission to develop the elements of a Position Paper on relationships between transportation noise and annoyance. This work was completed in August 2000 and the contents of the TNO report are reproduced in Annex I as a part of this Position Paper. The report describes in detail the process by which the results of a large number of studies and surveys were analysed to develop synthesised dose-response curves which can be used to estimate the number of annoyed persons or highly annoyed persons, given the noise exposure of their dwellings.

The present Position Paper summarises the recommended descriptors of noise exposure and of annoyance and recommends dose-effect curves, together with formulae. These curves are recommended for use in the context of the proposal for a Directive on the Assessment and Management of Environmental Noise.

Annex I of this document consists of the TNO report. Annex II of this document gives a concise overview of the meetings in which (parts of) the Position Paper were discussed and gives a list of the members of WG2.[1]

II – DESCRIPTORS

2.1. Noise exposure

Lden is defined in terms of the "average" levels during daytime, evening, and night-time, and applies a 5 dB penalty to noise in the evening and a 10 dB penalty to noise in the night.

The definition is as follows:

$$Lden = 10 \lg [(12/24).10^{LD/10} + (4/24).10^{(LE+5)/10} + (8/24).10^{(LN+10)/10}]$$

Here LD, LE, and LN are the A-weighted long term L_{Aeq} as defined in ISO 1996-2 (1987) for the day (7-19h), evening (19-23h), and night (23-7h) determined over the

[1] This document generally represents a consensus by the members of the Working Group. Not all experts necessarily share the views on every detail expressed in this document. It should not be considered as an official statement of the position of the European Commission. The European Commission and the French Ministry of the Environment made a financial contribution towards the expenses of the Working Group.

year at the most exposed facade. Lden has been put forward as the noise metric for the prediction of annoyance in the proposal for a Directive on the Assessment and Management of Environmental Noise.

2.2. Annoyance

This Position Paper recommends that the percentage of persons annoyed [%A], or the percentage of persons highly annoyed [%HA] be used as the descriptor of noise annoyance in a population. These descriptors of annoyance are derived from transforming various annoyance scales to a 0 to 100 basis and using a cut-off at the scale value 50 (for %A) or 72 (for %HA), respectively. Although this Position Paper does not make a final choice with respect to the annoyance descriptor, the selection of a single annoyance descriptor is recommended with a view to comparability. Initially, %A has been chosen by WG2 instead of the more widely used %HA, because %A is more sensitive to changes in annoyance (between 50 and 72) at lower noise exposure levels. Most comments on the draft version of this Position Paper that proposed %A as the descriptor of annoyance, pertained to this choice of the annoyance descriptor. Moreover, additional experience has been obtained with the application of annoyance descriptors in quantifying annoyance on the basis of noise maps. The Working group has not and will not convene to make a definite proposal taking into account the comments and the additional experience. The following brief discussion is given in order to facilitate the choice of a uniform annoyance descriptor, but does not necessarily reflect the position of all members of WG2.

2.3. Discussion

The choice of the annoyance descriptor depends on the framework within which it is to be used. Such a framework could encompass the following three elements:
1. Elimination of unacceptable levels (black spots) by a legal limit (U) in terms of Lden, possibly linked to the type of source;
2. Preservation and extension of quiet (residential and natural) areas (white areas) by policy targets in terms of the area where Lden does not exceed a certain value (L);
3. Improvement of the acoustical quality in residential areas where L < Lden < U (grey areas) by policy targets in terms of the prevalence of annoyance.

Then relationships between Lden and annoyance are needed to estimate the prevalence of annoyance (point 3) on the basis of noise maps. With relationships for %HA, the number of highly annoyed persons can be estimated; with relationships for %A, the number annoyed persons can be estimated. Alternatively, with relationships for the average annoyance, the 'total amount of annoyance' (Norwegian noise annoyance index = sum of estimated annoyance scores in the population) can be assessed. %HA has been most widely used. An important practical advantage over %A is that calculation of the number of annoyed persons using %A does require very low levels down to Lden = 37 dB(A) to be assessed, while determination of the number of highly annoyed persons using %HA does not require information on levels with Lden < 42 dB(A). An advantage of percentage measures such as %HA and %A

over the average annoyance is that the corresponding prevalence measures (number of highly annoyed persons, number of annoyed persons) are more easily understood by the public than prevalence measures on the basis of the average annoyance (noise annoyance index). Finally, experience made clear that the higher sensitivity of %HA to changes in the higher range of Lden and the lower sensitivity to changes in the lower range of Lden actually may be an advantage. Substantive reduction of any prevalence measure of annoyance (based on %HA, %A, or average annoyance) requires improvements in the lower part of the range between L and U, because the largest part of the population comes in that part of the range. In order to draw sufficient attention to persons in the higher part of grey areas, exposed to levels close to a legal limit (U), it appears to be an advantage that %HA is relatively sensitive to noise reductions in that range. There is no danger of neglecting quiet areas as a consequence of using %HA as the annoyance descriptor, if there is a separate stimulating the preservation and extension of quiet areas (white areas) (point 2).

III – RECOMMENDATIONS

The Position Paper recommends the use of the following relationships for the estimation of the noise annoyance (%A and % HA) on the basis of the noise exposure of dwellings. The exact formulas for the relationships that have been found (see Annex I) involve the formula for a normal distribution. The following polynomial approximations are easier to use and are sufficiently accurate for practical purposes:

Aircraft: $\%A = 8.588*10^{-6}\ (Lden-37)^3 + 1.777*10^{-2}\ (Lden-37)^2 + 1.221\ (Lden-37)$;
Road traffic: $\%A = 1.795*10^{-4}\ (Lden-37)^3 + 2.110*10^{-2}\ (Lden-37)^2 + 0.5353\ (Lden-37)$;
Railways: $\%A = 4.538*10^{-4}\ (Lden-37)^3 + 9.482*10^{-3}\ (Lden-37)^2 + 0.2129\ (Lden-37)$;

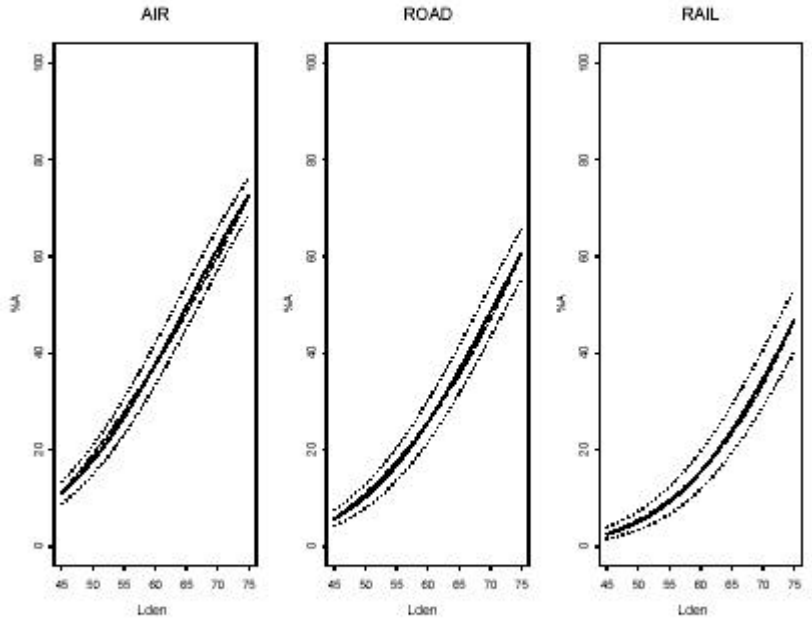
Aircraft: $\%HA = -9.199*10^{-5}\ (Lden-42)^3 + 3.932*10^{-2}\ (Lden-42)^2 + 0.2939\ (Lden-42)$;
Road traffic: $\%HA = 9.868*10^{-4}\ (Lden-42)^3 - 1.436*10^{-2}\ (Lden-42)^2 + 0.5118\ (Lden-42)$;
Railways $\%HA = 7.239*10^{-4}\ (Lden-42)^3 - 7.851*10^{-3}\ (Lden-42)^2 + 0.1695\ (Lden-42)$.

Figures 1 and 2 show that the approximations (dashed lines) are almost equal to the curves estimated on the basis of empirical data (solid lines). The figures also show the 95% confidence intervals around the curves (dotted lines).
Curves for annoyance using any cut-off (50,72, or another) can be derived on the basis of the information presented in the Annex of this Position Paper. Table 1 gives for various Lden values %A as well as %HA. The table illustrates that for one type of source there is a one-to one correspondence between %A and %HA. Consequently, for each limit in terms of %A there is an equivalent limit in terms of %HA (i.e., a %HA that corresponds to the same Lden). Vice versa, for each limit in terms of %HA there is an equivalent limit in terms of %A.

Table 1. % A and % HA at various noise exposure levels (Lden) for aircraft, road traffic, and rail traffic

Lden	Aircraft		Road traffic		Rail traffic	
	%A	%HA	%A	%HA	%A	%HA
45	11	1	6	1	3	0
50	19	5	11	4	5	1
55	28	10	18	6	10	2
60	38	17	26	10	15	5
65	48	26	35	16	23	9
70	60	37	47	25	34	14
75	73	49	61	37	47	23

Figure 1: The percentage annoyed persons (%A) as a function of the noise exposure of the dwelling (Lden). The solid lines are the estimated curves, and the dashed lines are the polynomial approximations. The figure also shows the 95% confidence intervals (dotted lines).



IV - APPLICATIONS AND LIMITATIONS

The dose-response functions and their curves recommended here are only to be used for aircraft, road traffic, and railway noise and for assessment of long term stable situations. They are to be utilised for strategic assessment, in particular in the context of Annex III of the proposal for a Directive relating to the assessment and management of environmental noise, in order to assess the effects of noise on populations in terms of annoyance. They can be used in target setting, in translating noise maps into overviews of numbers of persons annoyed (or highly annoyed, etc), in cost-benefit analysis and Environmental Health Impact Assessment. When used in Environmental Health Impact Assessment, they give insight in the situation that is expected in the long term. They are not applicable to local, complaint-type situations, or to the assessment of the short-term effects of a change of noise climate. The curves have been derived for adults. The curves are not recommended for specific sources such as helicopters, military low-flying aircraft, train shunting noise, shipping noise or aircraft noise on the ground [taxi-ing].

V - FUTURE DEVELOPMENTS

Relationships are presented in this Position Paper for aircraft, road traffic and railways,respectively. These are the most important sources of environmental noise in Europe. However, locally, the noise situation can be dominated by other types of sources. Specifically for such situations, there is a need for procedures that can be used to estimate the annoyance caused by these other types of sources, such as industrial sources. Also it has been acknowledged that some of the surveys included in the analyses were conducted some time ago when, for example, a different range of aircraft types were in use at certain airports. Work is in progress to add the most recent surveys to the database and also to conduct new surveys. Analyses to be published in the next year do no reveal any systematic changes of the dose-response functions over the time span (1965-1998) covered by the data sets used to establish the functions presented here. Furthermore, there is a need for quantifying the influence on annoyance of a relatively quiet façade, special insulation, and possible differences between Northern and Southern Member States of the EU. Working groups will pay attention to these issues in the coming years and will formulate an update of the present Position Paper if sufficient insights in these issues will be gained in that period.

Annex I
TNO Report PG/VGZ/00.052

Elements for a position paper on relationships Between transportation noise and annoyance

July 2000

(Results also published as: Miedema HME, Oudshoorn CGM. Annoyance from Transportation Noise: Relationships with Exposure Metrics Ldn and Lden and their Confidence Intervals. *Environmental Health Perspectives*, Vol. 109, 4, April 2001).

Annex II: Dates and History - Members of WG 2

WG 2 Meeting, 14 January 2000 (NPL, Teddington): Preliminary draft of exposure response relationships for noise annoyance for the Position Paper presented by Henk Miedema. Discussion followed.

WG2 Meeting, 12 May 2000 (Ministry of the Environment, Paris): Henk Miedema made a presentation of a paper to be submitted to a scientific journal. This paper will be the background for the position paper. Discussion followed.

WG2 Meeting, 31 August 2000 (Nice): The commissioned TNO report (PG/VGZ/00.052,July 2000) prepared by Henk Miedema and Catharina Oudshoorn has already been accepted by the Commission. A draft of the WG 2 Interim position paper will be produced by Bernard Berry and Henk Miedema on the basis of this TNO report. Comments of WG members will be submitted to Jacques Lambert (no later than 22 September 2000).

Steering Group Meeting (Brussels, 13 October 2000): Approval of WG2 position paper on dose-effect relations on the agenda. Jacques Lambert (Chairman of WG 2) presented the position paper. Discussion followed. SG members to provide comments to Cion by 15 December 2000.

WG2 Meeting 26 January 2001 (City of Amsterdam): Comments of the Steering Group to the WG 2 Position paper and revision of the Position paper (Jacques Lambert and Henk Miedema). Discussion followed

Steering Group Meeting (Brussels, 5 June 2001): Presentation of the revised Position Paper by Jacques Lambert (Chairman WG 2). SG members to provide comments to Cion by 15 July 2001.

Steering Group Meeting (Brussels, 7 December 2001): In the absence of Jacques Lambert (Chairman WG 2), Martin van den Berg presented WG2's position paper on dose-effect relations for the Lden indicator. CION thanked WG2 for their work, and asked them to finalise the paper with the full group, including a recommendation to the CION to publish the paper as an input to Annex III of the Environmental Noise Directive. WG 2 members to provide final comments to J. Lambert by 31 December 2001.

The members of WG2 are:

Jacques Lambert (chair), INRETS, France
Birgitta Berglund (co-chair), University of Stockholm, Sweden

Bernard F. Berry, NPL/ Bel-Acoustics, UK
Ton van Breemen, City of Amsterdam, Netherlands
Andrea Franchini, Agenzia Regionale Prevenzione e Ambiente, Italy
Isabel Lopez Barrio, Instituto de Acustica, Spain
Henk M.E. Miedema, TNO, Netherlands
Jens Ortscheid, Umweltbundesamt, Germany
Jose Palma (NGO - Quercus), University of Lisboa, Portugal
Tjeert ten Wolde, EC, Belgium
Shirley J. Thompson (WHO), University of South Carolina, USA
Ian Witter (ACI Europe), BAA Heathrow, UK

----------end of extract----------

4. THE DIRECTIVE

The Directive was officially adopted at a third reading in the European Parliament on 15 May 2002 , and by the Council on 21 May. It was published as DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on 25 June 2002.

Article 6 Clause 3 states

> 3. Harmful effects may be assessed by means of the dose effect

Annex III appears as follows;

> *ANNEX III*
> **ASSESSMENT METHODS FOR HARMFUL EFFECTS**
> referred to in Article 6(3)
> Dose-effect relations should be used to assess the effect of noise on populations. The dose-effect relations introduced by
> future revisions of this Annex in accordance with Article 13(2) will concern in particular:
> — the relation between annoyance and L_{den} for road, rail and air traffic noise, and for industrial noise,
> — the relation between sleep disturbance and L_{night} for road, rail and air traffic noise, and for industrial noise.
> If necessary, specific dose-effect relations could be presented for:
> — dwellings with special insulation against noise as defined in Annex VI,
> — dwellings with a quiet façade as defined in Annex VI,
> — different climates/different cultures,
> — vulnerable groups of the population,
> — tonal industrial noise,

The dose-effect relationships in the Position paper are thus regarded as those to be used in the Directive.

5. RECENT DEVELOPMENTS

Annex III of the Directive notes the potential for future revisions, thus future research and synthesis of survey data will allow extension and updating. Dr Tjeert ten Wolde, one of the

architects of the Directive, in a Keynote lecture at the 2002 Forum Acustucm, [8] outlined research needs in a series of tables. See below.

Table 4.- Research subjects related to the definition of effects and to dose-effects relations

Number	Subject	Aspects
8	Annoyance – L_{den} for traffic noises	Road, rail and air traffic noise
9	Selection of one effect (response) descriptor for sleep disturbance.	Shall correlate with L_{night}.
10	Further dose-effect relations for annoyance.	Northern and Southern Member Sates; houses that are especially insulated against road, rail or air traffic noise; industrial noise.
11	Dose-effect relations for sleep disturbance	The dose quantity is L_{night} ; all EU climates; road, rail and air traffic noises; specially insulated houses.
12	Dose-effect relations for children	Learning capability.

Dr ten Wolde emphasised the need to fill the gap relating to annoyance from industrial noise.

Sleep disturbance is the subject of a current EC Study contract to TNO, which involves a subcontract to BEL. A Draft report on this project has been considered by the EU Steering Group in September and publication is expected at the end of the year.

Dose-effect relations for effects on school children are the subject of the EC RANCH project See www.ranchproject.org

The World Health Organisation recently organised a Workshop of experts in Bonn. It noted that WHO Guidelines for Community noise were published in 2000, as the result of a WHO expert meeting, held in London in April 1999. The experts derived by consensus, guideline values for various adverse health impacts. These guidelines values are based on expert judgement of then existing exposure-response findings. At the time when the expert meeting took place, there was, apparently, not enough information available on the exposure-response relationships to consider developing curves, which would allow one to forecast the effects of exposure to various doses. This new meeting was proposed to help clearing some gaps using new scientific and medical studies about the exposure to noise nuisance and different responses, in order to establish exposure-response relationships functions between noise and subsequent effects on human health. Papers presented during the meeting were to cover the following themes:

- Sleep disturbance
- Hearing impairment
- Annoyance
- Loss of productivity on adults
- Loss of productivity on children (learning difficulties, loss of concentration)

For each of these themes proposals for exposure-response relationships for children and for adults were to be discussed and if possible agreed by consensus. Then a representative of each of the six regions of the WHO would make a presentation providing the group with

available information on the existing exposure data of the population to noise in his/her region.

The main product of the meeting was to be exposure – response (effects of noise on human) functions (curves) for different levels and sources of noise in children and adults. These curves would support the preparation of WHO guidelines. The instrument (e.g. web site) for best advising and supporting member states on this specific aspect of noise measurement and improving health of the population exposed to different noise sources were also to be discussed at the meeting.

At the time of writing, official output from the meeting is awaited

6. REFERENCES

1. European Commission. 2000. *Future European Directive relating to the Assessment and Management of Environmental Noise*, based on a proposal of the European Commission presented in COM(2000)468final,Brussels, 26.07.2000.

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7. Miedema, H. M. E. and Oudshoorn, C. G. M. 2001. *Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and Lden and Their Confidence Intervals.* Environmental Health; Vol 109: 4, 2001, 409-416.

8. T ten Wolde 2002. *The EU noise policy and its research needs*. Proceedings of EAA Forum Acusticum 2002. CDROM