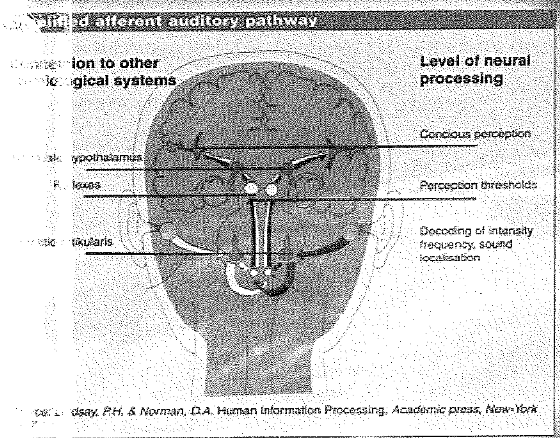
Traffic Noise Pollution
- A State-of-the-Art-Review -



A project supported by:

the European Commission, DG Health & Consumer Protection, Luxembourg

within the programme

"Pollution related diseases"

Sound level scale

P (in µPA)	dB	Subjective impression	Type of noise
200.000.000	140		Airplane take off at 50 m
	130		
20.000.000	120	Threshold of pain	Airplane take off at 300 m
	110	Tolerable for a short time	
2.000.000	100		Pneumatic hammer
	90	Very painful	Heavy trafficked street
200.000	80		
	70	Painful	Lively street
20.000	60		Common conversation
	50	Common	
2.000	40	Quiet	Library
	30		Forest
200	20	Very quiet	
	10		Acoustic laboratory
20	0	Threshold of hearing	

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Final Report

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Table of Contents

Abbreviations

A	= Austria	B	= Belgium	CH	= Switzerland
CZ	= Czech Republic	D	= Germany	F	= France
I	= Italy	IRL	= Ireland	NO	= Norway
NL	= Netherlands	S	= Sweden	E	= Spain
SI	= Slovenia	UK	= United Kingdom	YU	= Yugoslavia
EL	= Greece	USA	= America	EU	= Europe

dB	Decibel
dB(A)	A-weighted decibel
DIN	German Institute for Standardisation
EEG	Electroencephalogram
EFN	Norwegian flight noise index
EMG	Electromyogram
EOG	Electrooculogram
FBN	Swedish unit for a time-weighted mean level
Lax	≡ Sound Exposure Level (SEL)
L_{eq}	Equivalent continuous sound level
$L_{eq,24h}$	Equivalent continuous sound level for 24h
$L_{eq,16h}$	Equivalent continuous sound level for 16h (day)
$L_{eq,8h}$	Equivalent continuous sound level for 8h (night)
L_m	Mean level ≡ L_{eq}
L_{max}	Maximal level
L_{Amax}	A-weighted maximal level
L_{Asmax}	A weighted and slow weighted maximal level
L01	The level which in 1% of the measurement duration reaches or exceeded
L90	The level which in 90% of the measurement duration reaches or exceeded
NEF	Noise exposure forecast
NGO	Non governmental organisations
R^2	Determination coefficient (The factor R^2 shows the coherence between the published mean average values and the fitted curve)
RAS	Reticular arousal system
REM	Rapid eye movements (dream-time)
(NON REM)	Non rapid eye movements
RLS 90	German guidelines (Richtlinie für Lärmschutz an Straßen)
SEL	Sound Exposure Level

List of tables

List of figures

Abstract

The objective of this study was to identify different patterns of reaction to noise in northern, central and southern European regions.

Noise, irrespective of its origin, is an increasing issue in most European countries regardless of whether it is from traffic, industry or domestic sources. Population density and human activities in today's modern society, increase the need to move at a faster pace than those measures taken to reduce the influence of noise.

The situation, however, varies from one part of Europe to another. The acceptance of noise is also different in the regions studied. The predominant health effect from noise is auditory damage or a reduced ability to hear. This is caused by frequent exposure to industry activities, from "walkmans" and transport, etc.

The main effects from noise are annoyance and sleep disturbances. Annoyance creates discomfort and malaise, trouble, uncertainty and even fear or limitation in behaviour to avoid the discomforting sound. There seem to be thresholds of 55 dB(A) for outside activities, which demand attention and concentration, and 60 dB(A) when participating in a discussion. Voice levels need to be at least 10 dB(A) less than the surrounding noise to make a conversation possible.

In identifying the issues and reaching the objectives, a major literature search has been compared with the results from a questionnaire, replied to by experts and civil servants from the three regions. The Berlin Centre for Public Health has coordinated the work and collected information from Central Europe. CUSP in Madrid have provided the South European material and Strateco Development in Sweden collected the North European material. In general, the replies to the questionnaires have confirmed the results from the literature study.

The conclusions from the study are that sleeping hours vary in two aspects. Differing expectations of noise as well as different light conditions contribute to the major results in the northern and southern regions.

The different expectations, or habits, create a lower annoyance reaction from people surveyed in southern Europe in comparison to parts of central Europe and the majority of northern Europe. The results revile a greater sensitivity to noise in the north European countries for five main reasons. [1)]The lower density of population in the north that designate different space for recreational areas, industrial areas and traffic apart from each other more than in areas with higher density of population. [2)]The climate, which demands more insulation in the north which also limits disturbance indoors from outside activities. [3)]The very different light conditions which do not vary as much in the south as in the north. Consequently, it keeps the population active during later hours in the summer and less active during the winter period when parts of the population do not see daylight for weeks. [4)]The cold climate creates a need to sleep with closed windows even during summer time. During this time when the days can be hot, the nights can be as cold as in the high rise mountain areas in central Europe. [5)]The special siesta-culture in the south, taken advantage of by some 25 % of the population, where less noise is expected but rarely occurs due to the increase in economic activity. "The south is somewhat spoiled with heat and the north is sometimes somewhat spoiled with silence".

The recommendations issued as a result of the findings in this study is twofold:

- Firstly, a standardised European interviewing and testing inventory e.g. for sleep disorders, is urgently needed in order to examine the effect of noise on sleep disorders comparable in all parts of Europe.
- Secondly, the process of standardisation needs to take the physical and cultural differences inside the EU into consideration.

1 Health effects connected to traffic noise and other factors

Noise, irrespective of its source – road, rail or air traffic, industry, or neighbourhood activities – remains a key issue in most European countries.

Transport is still the main source of noise, ahead of other external sources such as industry or building works and road traffic is by far the main source of traffic noise in European countries. In most countries aircraft noise is the second biggest source of noise, followed by railway noise and finally noise from fixed sources.

However, the situation varies from one European country to the next, from "fairly noisy" countries such as those situated in southern European to "fairly quiet" countries such as those situated in the Nordic region. Train noise is also quite high in countries like Germany or Switzerland [OECD, 1991]. In Europe, the proportion of the population exposed to environmental noise above 65 dB(A) has increased during the past decade from 15% to 26% [Lercher, 1996].

The predominant health effect of noise is auditory damage which includes hearing loss. This is frequently caused by loud work noise or by loud music (i.e. from continuous exposure to walkmans and discotheques) as well as by loud firecrackers. Besides these auditory noise effects attention is also paid to the non-auditory effects of noise. Non-auditory effects of noise appear to occur at levels far below those required to damage the hearing organ, and are mostly subdivided into annoyance, sleeplessness and vegetative hormonal reactions.

1.1 Annoyance

A central effect of noise is annoyance. Lindvall et al. (1973) defines annoyance as a feeling of discomfort which is connected to adverse influencing of an individual or a group to any substance or circumstance. Annoyance expresses itself e.g. by malaise, fear, threat, trouble, uncertainty, restricted liberty experience, excitability or defencelessness.

Noise, vibrations and smells cause annoyance according to the level of their appearance. This is the case if a person or persons exposed to noise try to decrease or avoid their exposure to the noise or if they try to leave the exposed area. On the one hand annoyance is influenced by sound-related variables (mediatory factors), and on the other by variables related to the individual or the exposed group (moderatory factors). To seriously take into consideration these influences is often a more reliable method for the judgement of a concrete acoustic situation than by simply applying a limitation to the sound levels. As a conscious perception process, annoyance shows itself with different intensity through emotional reactions and therefore as changes of the vegetative and hormonal regulation process (Cannon 1928, Simonow 1975, Felker et al.1998).

1.2 Moderatory factors

Moderatory factors are categorised by personal factors and specific situations which influence the transformation of a sound experience into annoyance. Additional elements of this factor in the medical psychological sense should be mentioned with regard to the question concerning so-called "primary noise sensitiveness", which one allocates to particularly introverted persons. Noise sensitiveness or even noise over-sensitivity can also be acquired during a secondary phase and reflected in the current noise reaction (sensitisation, also polarisation, up to 15 dB). Other personal factors are age, family and other social factors, positive or negative pre-experiences with noise or the source of noise production, profession and living conditions.

One of the most important moderatory factors is the influence of the situation. Noises which are experienced in the open air or in the laboratory with an absence of annoyance can trigger strong annoyance reactions in other locations i.e. at home, where reactions up to levels of desperation and in particular helplessness occur. A typical example of this incident occurs if you were unable to leave your home due to illness or physical handicap.

The appearance of annoyance must consequently demonstrate a large affected area whereby individual levels of annoyance cannot be calculated by normal noise levels. The quantification of noise annoyance using multi-level psychometric scales and the correlation of the data thus obtained with the respective physical characteristics determined for noise emission provides a good overview of the interaction of noise impairment and exposure (dose-effect ratio). Annoyance comprises, among other things, the extent of sleep impairment, relaxation, intellectual work, acoustic communication and, generally, interference with intentions and capabilities.

1.3 Sleep impairment

Sleep is an essential condition for man and can be severely disturbed by noise. Sudden sleep disturbances affect the subjective health and with an individual latency, also affect the qualitative or quantitative ability. Chronic forms of sleeplessness can be classified as a health risk.

Sleep, sleep stages and sleep structure:

Sleep is not simply a condition of general motor, sensory, vegetative and emotional quietness but has rather complex dynamics. The characteristic features of human sleep are cyclic, dynamics, changed motoricity and sensoricity as well as a change in levels of consciousness. By analysing the results of the electroencephalogram (EEG), the electromyogram (EMG) and the electrooculogram (EOG) it is possible to describe and to judge objectively the dynamics of sleep (course of sleep). In accordance with the criteria of Rechtschaffen and Kales [1968], it is possible to distinguish an REM sleep stage (rapid eye movements) and four NON REM sleep stages. The cyclical sleep progress of a young healthy sleeper is represented in Fig. 1.

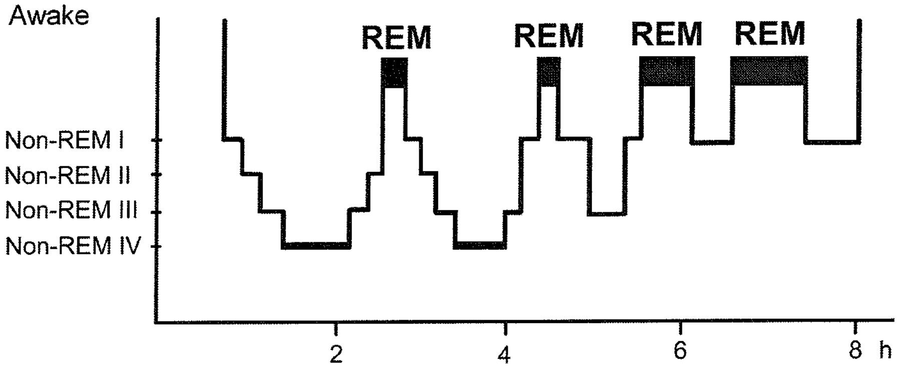


Fig. 1: Cyclical progress sleep of a young, healthy sleeper (source: Hecht 1992, 1998)

The stages most important to the relaxation of human beings are stages III & IV of the NON REM sleep (delta sleep) and REM sleep. The delta sleep (deep sleep) is required for physical recuperation and REM sleep (dream sleep) for the mental-emotional recuperation as well as for the continuous upkeep of the individual's relationship program where the transfer from short- to the long term memory takes place.

The emotional component of sleep also has to be taken into account along with the biological. Any disturbance during sleep at night is considered by human beings as being something unpleasant when it is judged to interfere in private life. Waking up during sleep at night is defined as an unpleasant experience and thus causes negative emotional conditions.

1.4 Effects of noise on sleep

All objectively measurable and/or subjectively perceived deviations from normal sleep are depicted as deviations from normal sleep pattern [Griefahn 1985]. Sleep disturbances can be caused both endogenously and by exogenous irritations. Noise is one of the leaders of exogenous irritations. Sleep disturbances caused by noise can be classified on the basis of chronological sequence into primary and secondary reactions.

Elements of the primary reactions include:

- short-term changes in the EEG (zero reactions),
- superficiality of the depth of short-term sleep (stage change) up to awakening,
- changes of sleep stage distribution,
- extension of the latent periods (in particular the fall asleep latency),
- increase (duration) of periods of high muscle strain (body movements),
- shortening of total sleep period;

as well as vegetative reactions such as:

- changes in breathing frequency,
- changes in hormone distribution and
- changes in the peripheral circulation.

Secondary reactions are reversible impairments of the general condition after waking up. These include consideration of:

- the physical constitution,
- the emotional constitution,
- the sleep-experience,
- the well-being,
- capability and
- concentration.

Disturbance of sleep through noise is related to changes in the vegetative hormonal system. The sensitiveness of the indicator systems becomes lower for EEG, vegetative hormonal reactions (heart frequency, peripheral vasoconstriction, hormone secretion) and motoricity. Repeated or continuous noise attractions in the sleep cause an activation of the nervous system which shows in the EEG by intermittent noises as a disturbance of the chronological structure, i.e. destruction of the sleep cycles and by virtually continuous noises as superficial sleep. Both kinds of noise lead to a shortening of the deep sleep times (stages III & IV) of the REM phases and to a disturbance of the cyclical progress of sleep.

A typical sleep cyclical progress of a young, healthy sleeper with intermittent noise (aircraft noise) is represented in the Fig. 2.

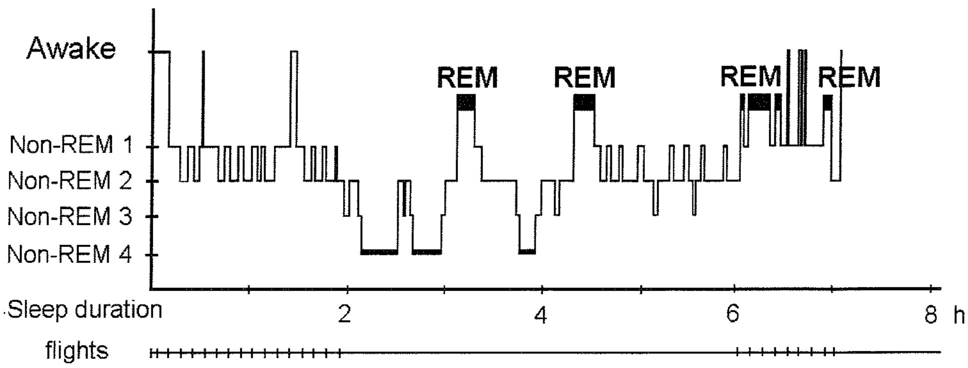


Fig. 2: Cyclical progress of sleep of a young sleeper with intermittent noise (aircraft noise) (source: Maschke 1995, 1999)

The cyclical sleep progress shows the destruction of sleep architecture through the noise-induced activation and is connected with a more superficial sleep.

The noise induced activation can lead to awakenings. Apart from unusual physical features of the noise disturbance - particularly intermittently – the information content of the noise is significant to the sleeper. The alarm function of the auditory system can lead to awakenings from gentle noise levels if unknown information or information which does not signify danger is contained in the noise. On the other hand, an unexpected non-appearance of the chronically familiar noise can also lead to awakenings (e.g. cancellation of an infrequent but regular train service). With less unusual noises a significant increase in the number of the people woken up only appears above 40 dB (A). Remarkably high noise levels of 90 dB (A) and above can be slept through, particularly by children. The wake up effect is not only dependent on the extent of the noise level, but also on its distance to the respective basic noise level. The level difference between basic noise level and maximum level e.g. at nightly individual events should not amount to greater than 10 dB (A).

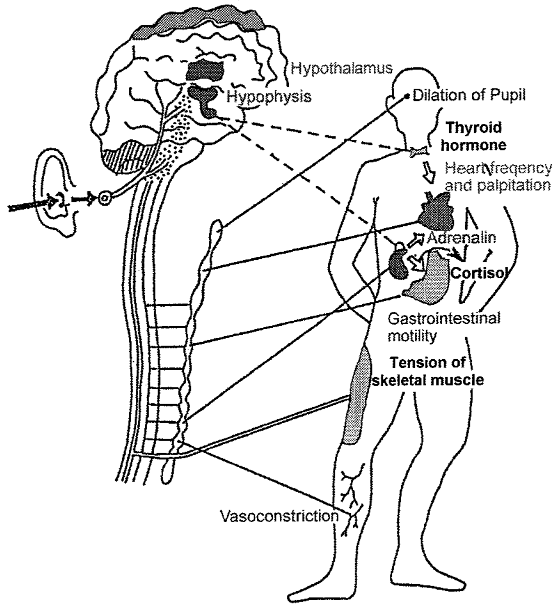
In principle, frequent disturbance of physiologically programmed functions must be regarded as critical to health. This also applies to awakenings. Noise induced awake phases must be judged as abnormal and assessed as a long-term health risk. On the other hand a sharp disturbance of physiological functions should even be recorded below the consciousness threshold.

Studies by Maschke et al. (1992) on residents near an airport who have been exposed to aircraft noise for a long time revealed a double increase in adrenaline concentration (over an 8 hour urine collection period). The authors pointed out that cortisol secretions, which have since increased, are to be classified as potentially stress health-related (Maschke et al. 1995, 1997 a,b).

1.5 Vegetative hormonal system

Environmental stress factors consist of physical, chemical and psycho-socio components which can be perceived by any human being individually. Psychological effects concern feeling of fear, depression, frustration, irritation, anger, helplessness, sorrow and disappointment. Psychological and behavioral stress may have an indirect effect on physiological processes within the body [Passchier-Vermeer 1993]

The auditory system is structured in such a way that acoustic signals can very easily induce acute physiological stress-effects. An acoustical signal will be transmitted by neural connections not only to the auditory cortex - in order to be heard – but also to the reticular arousal system (RAS) and the hypothalamus, the centre regulating of the autonomic activity in the body. Activation of both systems triggers physiological stress effects.



Quelle: modifiziert nach Ising 1993

Fig. 3: Simplified noise induced vegetative hormonal reactions (source: Ising 1993 modified)

A stressor can lead to very different reactions by different persons (theoretical stress model) [Seefeld 1989]. Two types of stress induced activation can essentially be distinguished.. One results in the individual stopping the stress reaction on his own, i.e. a controlled stress reaction (Eustress) accompanied e.g. by a temporarily increased catecholamine, increased pulse frequency and moderate raise of the plasma testosterone. With the controlled stress reaction the individual has self-control strategies, however this can only start with effort. If this fails, the self-control changes into an uncontrollable stress reaction appears which inevitably results in particularly increased corticoid level.

On the other hand, uncontrollable stress (distress) describes a process which the individual cannot cope with. This means either the available self-control capacity cannot be used suitably to deal with the situation or else the situation is unsuitable for self-control. The resulting dysregulations can become conditioned and with any repetition the disturbed process is always manifested more strongly [King 1996; Pawlow 1927; Traue 1999].

An insufficient stress self-control leads to regulation disturbances and ultimately to stress induced illnesses (e.g. arteriosclerosis, coronary heart conditions, essential hypertension).

The illness starts to develop if the regulation abilities of the body are no longer sufficient to compensate the stress. In that context, noise induced illnesses are not only absolutely organically provable damage like be treated by classic medicine, but also functional disturbances of the emotional biological process which cannot be separated from each other.

Environmental influences and the individual assessment of situation requests are therefore of great importance.

1.6 Noise and stress

A classic long term study by Graff [Graff 1968] shows the development of cardiovascular diseases at high noise exposure (work noise). This study involved 117 employees of a boiler forge in a metal processing company (Bergmann-Borsig, Berlin-Wilhelmsruh). The average sound level was 95 dB(A) and the peak levels reached 120 dB(A).

The data obtained was then compared with that of a control group. The control group was composed of transport workers, all of whom were of a similar age and who were exposed to the same sound levels of 50-60 dB(A) (n=78). The study was carried out using a complex circulatory diagnosis technique with particular emphasis on arterial hypertonia. The participants were all aged between 20-25 years of age upon commencing employment. Their cardiovascular health was confirmed by means of a company medical examination carried out before they commenced employment.

Graff and her colleagues studied the staff after 6 years service and again after 13.5 years (permanently employed in the boiler forge). After 6 years, 31% of the participants working in the boiler forge showed symptoms of level one hypertonia. In the control group of transport workers, 6% showed symptoms of level one hypertonia. None of the remaining participants in both groups (69% and 94% respectively) displayed any cardiovascular symptoms. After 13.5 years of service in the boiler forge, 38% of the participants displayed symptoms of level 2 or 3 arterial hypertonia. A further 43% displayed symptoms of level one hypertonia. The findings from both groups with hypertonia indicated further symptoms of cardiovascular disorders. Only 19% were found to be free of cardiovascular disorders. In the control group, 16% of participants displayed pathological cardiovascular symptoms at this point in time. 84% displayed no symptoms.

Table 1: Development of the cardiovascular disorders in workers at the Bergmann-Borsig boiler plant (Source: Graff 1968)

	Percentage of persons with cardiovascular disorders		
	Commenced employment	**6 year follow up**	**13 ½ year follow up**
boiler forge worker 95 dB(A)	0	31	81
transport worker 50 - 60 dB(A)	0	6	16

The noise pollution is therefore not only related to acute reactions but also to chronic stress reactions. The results are in close relation to the central nervous, vegetative, hormonal and immological systems. Noise such as physical and psycho-social stress factors causes non-specific stress reactions on the general vegetative excitatory processes in the organism. This happens, on one hand, directly to synaptic interactions of the auditory pathway to other nervous structures in the formatio reticularis and parts of the interbrain and, on the other hand, indirectly to the cortical and sub-cortical processing of the sound, i.e. cognitive and emotional processes under substantial participation of the limbic system [Cannon 1929; Mc Lean 1949; Lindsley 1951; Traue 1999; Hecht 2000]. Therefore, when assessing noise induced reactions one must always distinguish between acute false regulation (overdriving) and chronic overloading (overload). A perpetually recurring overdrive must also be classified as a health risk in terms of an overload through long term untreated exposure.

Following this general description for the non-auditory effects of noise a summary of the current relevant literature will be presented for south, central and northern Europe, since the non-auditory effects are influenced e.g. by culture, climate and regional habits.

This local literature was compiled on the basis of questionnaires completed relating to annoyance, sleeplessness and the vegetative hormonal reactions. Noise effect researchers from all European countries as well as authorities and representative citizen-initiatives took part in the study. These experts fill in the relevant literature for their region / their country (grey literature).

The relevant literature of the international databases is listed separately in the annexes.

- Overview of existing relevant data (State-of-the-Art review)
- Epidemiological data on traffic noise pollution in Southern Europe
- Epidemiological data on traffic noise pollution in Central Europe

2 Overview of existing relevant data (State-of-the-Art report)

A lot of information and literature on traffic noise pollution is existing in the environment on the respective experts. But not, of course, not all information is know by every expert. Thus, in order to include in this study also those information to which the experts involved in this project have no direct access, a questionnaire has been developed in order to learn about literature and information sources.

This questionnaire has been sent to over 100 experts in traffic noise pollution across Europe, including the EU Member States, Switzerland and the Baltics. The answers has been grouped according to geographical aspects:

- Southern Europe includes Portugal, Spain, Southern France, Italy and Greece,
- Central Europe corresponds to the Great Britain, Ireland, France, Austria, Netherlands, Belgium, Luxembourg, Germany as well as Switzerland,
- Northern Europe comprehends Sweden, Finland, Denmark, Norway and the Baltic States.

2.1 Epidemiologic data on traffic noise pollution in Southern Europe

2.1.1 Literature

Traffic noise is recognised as a major problem affecting urban environmental health in the southern region of Europe, since most big cities suffer chronic noise levels up the critical value of 65 dB(A). However, research carried out on health effects, relating to exposure to unhealthy noise levels in the Mediterranean European countries, is detailed enough to provide a full overview of its consequences. There are few research teams working in this field and related references are dispersed around this chosen region.

The data was gathered from university libraries as well as the experts' references from the questionnaires.

The majority of the grey literature reviewed in South Europe shows a clear pattern: it focuses mainly on noise subjective reaction and annoyance as much as sleep disturbances. Laboratory studies to measure physiological noise reaction in the human organism are rare, even when noise is considered a major contributing factor to environmental stress reaction, with the consequent neurological and hormonal reactions that can produce negative health consequences. The results of the works are as follows.

2.1.2 Annoyances

This is the most investigated health related issue, probably because it is the major cause of many official complaints. Most of the research carried out has been gathered by assessing noise interference in relation to personal habits and daily activities. A questionnaire was implemented to gather the information and subsequently to evaluate causes and trends.

By reviewing currently available documentation, the first step was to determine a selection of "black points" (> 65 dBA) or "grey points" (55 to 65 dBA) over the city or neighbourhood noise map and associate them with traffic present in the area. Secondly, representative samples of those affected by noise pollution were asked to fill in the attached questionnaire.

The most representative grey literature papers found in the Southern European region are given in Table 2. The results from these studies show that annoyances are very common effects in these latitudes and, of course, depend on the noise quality and quantity.

A good example of these kind of papers are the Lopez Barrio et al. works, one of which takes into account the importance of an acoustical isolation in a school located near an airport and a highway. This study had two stages, one before the isolation and the another afterwards. The first phase shows that teachers had to raise their voices during classes whereas the students show irritability, tension and exhaustion at the end of the school journey. After the isolation phase, the teachers expressed their satisfaction from the results. They affirmed that annoyances and communication interference diminished, in particular with regard to word perception. Therefore the insulation improved educational levels.

Communication interference therefore increases when noise levels go 10 dBA over voice emission levels (50 to 60 dBA). In addition, 65 dBA of environmental noise seriously affects speech intelligibility, with a major impact on educational factors.

One extreme case determined from one study is that of the educational effects of noise on a couple of schools sited in Torrejon (Madrid) close to the neighbourhood airport. Aircraft noise levels were detected as high (at 103 dBA), together with 70 dBA from road traffic (from a nearby motorway). The teachers identified this noise as the most negative effect on children's concentration.

The results of a variety of similar studies show differing degrees of performance losses are produced by different kinds of noise. Intense and unpredictable noises are worse than stable or continuous ones. It is also important to classify the type of task being carried out. The most affected are the high attention intellectual tasks whereas "easier" manual labour jobs are less affected.

One of the most important research areas implemented in the study (mostly by López Barrio et al.) is that children suffer from serious cognitive development damage.

It is also important to mention that the main effects of high noise levels on aggressiveness, in particular, expose those who are more inclined or predisposed to it (Herranz et al & Garcia, A).

Table 2: Most representative grey literature papers on annoyance for traffic noise found in Southern Europe

AUTHOR	TITLE	YEAR	COUNTRY
Herranz Pascual, K.	Mapa sonoro y estudio psicosocial de la respuesta de la población residencial de las ciudades de Avila, Palencia, Salamanca, Segovia y Zamora	2000	E
Callegari, A. et al.	Rassegna degli effetti derivanti dall´esposizione al rumore	2000	I
Kountouris, D.	The effects of noisy urban environment may cause the loss of memory to the elderly person	2000	EL
Herranz Pascual, K.	Avance del estudio psicosocial de la respuesta al ruido ambiental de la población residencial en el municipio de Ávila	1999	E
García, A. et al.	Evaluación de la molestia producida por el ruido ambiental	1999	E
Vela, A.	Valoración de los efectos producidos por fuentes de ruido urbano en los residentes de Pamplona, Valencia y Algemesí	1999	E
Herranz Pascual, K.	Estudio psicosocial de los efectos del ruido ambiental en la población residencial	1999	E
Beyragued, L.	Santé et environnement à Villeurbanne	1998	F
Remy, N. et al.	Intégation sonore de grandes infraestructures routiéres en milieu rural & périurbain	1998	F
Arriaga Sanz, J.	Percepción social de la contaminación acústica en Andalucía	1997	E
Alamar, M. et al.	La exposición cotidiana al ruido ambiental: evaluación de la contaminación sonora en Alcoi (Alicante)	1996	E
Larburu, K. et al.	Molestias producidas por el ruido ambiental urbano en Eibar y Arrasate-Mondragón	1996	E
Herranz Pascual, K.	Calidad ambiental percibida y molestia frente al ruido de tráfico en grandes ciudades	1994	E
Alvarado, J.	Behaviour and performance of scholars in a very noisy school	1994	E
Herranz Pascual, K.	Bruit de circulation et reaction subjective: analyse des differents indices de mesure de reponse a làmbiance de bruit	1994	E
García, A. et al.	Algunas consideraciones sobre la contaminación acústica y sus efectos en zonas urbanas	1994	E
Sanz, A. et al.	Los efectos del ruido de tráfico sobre el rendimiento de los alumnos en colegios de enseñanza primaria	1993	E

López Barrio, I. et al.	Reacción subjetiva al ruido de trenes. Percepción de una intervención ambiental (barrera acústica)	1993	E
López Barrio, I. et al.	Subjective response to traffic noise. The importance given to noise environment in choosing a place of residence.	1993	E
Suárez Varela, M.	Evaluation of the Environment Noise effects on the population of the historical centre of Valencia	1992	E
López Barrio, et al.	The effect of a noise abatement program on the attention capacity and reading ability of school children	1992	E
García, A. et al.	La respuesta subjetiva al ruido ambiental. Revisión de diferentes estudios realizados en la Comunidad Valenciana entre los años 1981 y 1991	1992	E
Fernández, A. et al.	Influencia del ruido en la patología humana	1992	E
Herranz Pascual, K. et al.	Respuesta subjetiva de molestia al ruido interior producido por los vecinos	1991	E
López Barrio, I. et al.	Evaluación de los efectos del ruido en profesores y alumnos antes y después del aislamiento	1990	E
García, A. et al.	Estudio del ruido producido por el tráfico en Valencia	1984	E

2.1.3 Sleep disturbances

Sleep disturbances have been the object of many researches due to numerous different consequences derived from noise exposure, particularly traffic noise. There are two types of effects.

Primary effects are those which occur during noise exposure and consist of insomnia, difficulty in getting to sleep and waking up twice or three times during the night. An example of one study carried out in Valencia (Llopis et al), shows that 40% of a population sample of 263 people who were questioned, answered that they " have difficulty in getting to sleep", the rest declared "that they stayed awake through the whole night". Both groups explained that traffic noise was the main cause of these symptoms.

Secondary effects occur on the day after the above symptoms, with changes in mood, tiredness, and diminishment of physical and mental performance.

Some authors (10, 11) agree that noise related sleep disturbances are significant when the equivalent noise levels (Leq) exceed 35 dBA indoors. In general, they advise, that during the night, outdoor noise levels must not surpass 45 dBA.

The most important grey literature found on sleep disturbances are given in Table 3.

Table 3: Most important grey literature found on sleep disturbances found in Southern Europe

AUTHOR	TITLE	YEAR	COUNTRY
Guijarro, D. et al.	Efectos del ruido ambiental sobre el sueño de los residentes en zonas urbanas	1996	E
López Barrio, I. et al.	Ruido de tráfico e interferencia en el sueño	1991	E
Llopis González, A. et al	Alteraciones del sueño producidas por el ruido ambiental	1989	E

2.1.4 Vegetative / hormonal reactions and consequences to noise

This field of research is at the moment one of the least developed in the Southern European region. At present, only two research teams have been found working on this issue (Martimportugués et al & Garabedian) after reviewing relevant literature from the entire region. Another team working on the epidemiological and statistical reflect, rather than the biological mechanism of noise health reaction has been added to these two teams (Diaz et al).

The documents describing vegetative / hormonal reactions and their consequences, are shown in Table 4.

The Martimportugués research was carried out in the human's laboratory of the Psychology Faculty of Malaga University. It was an experimental study where the main points considered were noise and overcrowding.

The sample was made up of 40 students from the Psychology department. They were allocated to four different experimental conditions with the same number of women and men and then submitted to cognitive proof. Afterwards, the heart rate and blood pressure were measured. Adrenaline, nor adrenaline, cortisol, ACHT and beta-endorphin were measured through biochemical analysis.

The outcome of this paper shows that the vegetative system reacts to noise and exposure to overcrowding with an increase of blood pressure, more systolic than diastolic, and an enhancement of catecolaminas, in particular nor adrenaline, cortisol, ACHT and Beta endorphin levels.

The research acquires more relevance when this environmental pollutant affects children. One work carried out in France by Garabedian describes the noise health consequences in this age group. In the *prenatal period*, for example, high frequencies can filter through the mother's abdominal wall. Over 105 dBA can induce movements from the 24th week of gestation. The same intensity increases the heart rate from 32nd week of gestation. Noise levels of 95 to 100 dBA can continuously produce both auditory and non auditory risks.

The noise induced health effects on neonates produced by the incubator is not a negligible matter, not only from the service activity noise but also from the noises made by new-borns in the incubator and rebound noise. *New-borns*, of a weight lower than 2500 grams, were observed in areas near airports. An association with Lactogen-placentaria hormone diminishment was observed after 24 weeks of gestation. The majority of premature births are girls, due to indirect noise effects caused through noise induced stress.

Noise can also generate stress on *school children* through an increase in heart rate and blood pressure (more than 90 dBA). Other manifestations consist of nausea, dizziness, gastrointestinal problems, tiredness and behaviour trouble such as aggressiveness and sleep disturbances which occur from 35 dBA.

Teenagers, usually get involved with activities that generate noise like music (100-110 dBA) motorcycle (90-100 dBA) and the like. Therefore, the author concludes that noise effects can affect the development of children at all ages

One interesting research result is that of the Spanish Diaz et al. team, whose aim it is to diagnose noise as a risk factor in the city of Madrid and evaluate the effects of traffic noise levels on emergency admissions to the city's main hospital. This is an epidemiological, longitudinal and ecological study using ARIMA multivariate time-series statistical analysis. Tests with this method were made prior to the study to evaluate environmental pollution effects on mortality and morbidity in different European and American cities. The variables considered as model inputs were: acoustic pollution and confusing variables as meteorological conditions and air pollution.

The results of these studies conclude that a strong relationship exists between traffic noise levels and the amount of emergency cases, taking into consideration the role of other confusing variables. Traffic noise is the most significant external variable for emergency admission, especially by cardiovascular pathologies, followed by atmospheric pollutants and temperature. A 5% enhancement of admissions has been detected for each dB over 65 dBA.

For this research team, noise could be an indicator of the strong anthropogenic activity of the city, showing synergetic effects with the other stressors linked to traffic, on people's health.

These findings are coherent with the model proposed, therefore more research is needed to elucidate biological mechanisms and to validate the results in other European cities.

Table 4: Documents describing vegetative/ hormonal reactions and consequences in Southern Europe

AUTHOR	TITLE	YEAR	COUNTRY
Díaz, J. et al.	Use of Poison regression and time series analysis to evaluate the short-term effects of environmental noise levels on health in Madrid, Spain	2001	E
Martimportugués, Cl.	Los efectos simultáneos del ruido y del hacinamiento	2000	E
Díaz, J.	Contaminación atmosférica y ruido. Sus efectos en salud	2000	E
Garabedian, E.	Effets du bruit sur la santé de l'ènfant	1999	F
Brandenberger, G. et al.	Failure of noise exposure to modify temporal patterns of plasma cortisol in man	1977	F

2.1.5 Questionnaires

Questionnaires were sent to 87 experts throughout Southern Europe. 19 positive answers (21.8%) were received, most of them coming from Spain as can be seen in the Table 5

Most of the questionnaires were sent by electronic mail and some of them by post and by fax.

Table 5: Geographical distribution of the questionnaire answers from Southern European Experts

COUNTRY	SENT	ANSWERED	PERCENTAGE
Spain	33	14 (1)*	39.4%
France	22	2	9.1%
Italy	15	1*	6.7%
Portugal	8	1	12.5%
Greece	9	1	11.1%
TOTAL	87	19	21.8%

* These questionnaires were answered by two experts

Table 5 shows that most of the experts did not answer our request. Some said that they did not have enough experience on this matter in spite of their work and one thought that the questionnaire was not relevant. We simply received no answer from the remaining experts.

From Portugal, the Ministry of Environment informed us that there are no specific studies on traffic-noise and related health effects. Nevertheless we made contact with eight experts and received just one answered questionnaire.

In the same way, we sent the questionnaire to local non-governmental Southern European organisations (NGOs) “Greenpeace”, “Friends of the world” and the Spanish “Ecologistas en acción” and only “Friends of the earth - Italy” and the Spanish group delivered an answered questionnaire.

2.2 Epidemiologic data on traffic noise pollution in Central Europe

2.2.1 Literature

In order to include regional (not internationally known) literature in the study, questionnaires were sent out to experts (noise effects experts, authorities, citizen-initiatives). In addition to the questions the experts were asked to name no more than 10 relevant literature studies respectively relating to annoyance, sleeplessness and vegetative hormone reactions. The questions included, for example: "(Please list (up to) 10 of the most important literature sources (reports, pamphlets, grey literature) handling regional/local noise-induced annoyances / noise-induced sleep disturbance / noise-induced vegetative-hormonal reactions)".

The results are presented in Table 6

Table 6: Literature in Central Europe on sleep disturbance

AUTHOR	TITLE	YEAR	COUNTRY
Griefahn, B	Sleep patterns and noise	1985	D
Gros, E	Noise, sleep and ability	1985	D
Gottlob,D	Disturbances of night-time sleep by aircraft noise	1989	D
Griefahn, B	Preventative medical suggestions for night-time noise protection	1990	D
Vallet,M. u. I. Vallet	Night-time flight index and results from sleep research	1991	F
Passchier Vermeer, W	Noise and health	1993	NL
Staatsen B.A.M., Franssen E.A.M et al.	Health Analysis for Schiphol Airport	1993	NL
Jong, de R.G., Opmeer, C.H.J.M., Miedema, H.M.E	Hinder door milieuverontreiniging in Nederland. Effecten van geluid, geur, trillingen, stof, verlichting en onveiligheid, peiling	1994	NL
Ärztinnen und Ärzte für Umweltschutz (Hrsg.)	Lärm und Gesundheit	1995	CH
Interdis. Arbeitskreis für Lärmwirkungsfragen	Impairment of sleep by noise	1996	D
Maschke et al.	Medical Report on Noise Hamburg Vorfeld II	1996	D
Maschke, C., Pleines et al.	Night-time aircraft effects and its influence on health	1996	D
Spreng, M.	Official notes on the discussion at the Senate on the 25.6.1996	1996	D
Maschke, Ising, Hecht	Sleep, nightly traffic, noise, stress, health	1997	D
Bundesamt für Umwelt, Wald und Landschaft (Hrsg.):	Schriftenreihe Umwelt Nr. 296: Belastungsgrenzwerte für den Lärm der Landesflughäfen, 6. Teilbericht der Eidgenössischen Kommission von Lärm-Immissionsgrenzwerte	1998	CH
Hecht et al.	Medical Report on Noise DA- Erweiterung Hamburg	1999	D
Oeser, Beckers (Hrsg	Federal Association for Aircraft Noise: Aircraft noise 2000	1999	D
Maschke Hecht	Testimonial statement on the medical reports M8 und M9 Schönefeld Airport Extension	2000	D
Ortscheid, Wende, H	The effects of aircraft noise	2000	D
RIVM,	Nationale Milieuverkenning 2000-2030	2000	NL
RIVM	Milieubalans 2000. Het Nederlandsa milieu verklaad	2000	NL

Table 7: Literature from Central Europe on vegetative hormonal reaction

AUTHOR	TITLE	YEAR	COUNTRY
Ising, H	Lärmwirkung bei besonderen Personengruppen	1987	D
Ising, H. u. E. Rebentisch	Ergebnisse einer Tieffluglärm-Studie in der Bundesrepublik Deutschland.	1991	D
Ising, H. u. B. Kruppa (Hrsg):	Lärm und Krankheit Noise and Disease	1993	D
Passchier Vermeer, W	Noise and health	1993	NL
Staatsen B.A.M., Franssen E.A.M et al.	Gezondheitskundige evalutie Schiphol	1993	NL
Jong, de R.G., Opmeer, C.H.J.M., Miedema, H.M.E	Hinder door milieuverontreiniging in Nederland. Effecten van geluid, geur, trillingen, stof, verlichting en onveiligheid, peiling	1994	NL
Maschke, C., Arndt, D., Ising, H et al.	Der Einfluß von Nachtfluglärm auf die Streßhormonausscheidung von Flughafenanwohnern	1994	D
Ärztinnen und Ärzte für Umweltschutz (Hrsg.)	Lärm und Gesundheit	1995	CH
Maschke, C., Arndt, D., Ising, H et al.	Nachtfluglärmwirkungen auf Anwohner. Ergebnisbericht über die Feldstudie: "Der Einfluß von Nachtfluglärm auf die Streßhormonausscheidung von Flughafenanwohnern	1995	D
Spreng M	Niederschrift des Erörterungstermins des 7. Senates am 25.6.1996	1996	D
Bundesamt für Umwelt, Wald und Landschaft (Hrsg.):	Schriftenreihe Umwelt Nr. 296: Belastungsgrenzwerte für den Lärm der Landesflughäfen, 6. Teilbericht der Eidgenössischen Kommission von Lärm-Immissionsgrenzwerte	1998	CH
Bezirksamt Köpenick	Umweltkapazität von Flughäfen. Aspekte der Lärmwirkungsforschung. Schutzziele und Schutzmaßnahmen	1999	D
Hecht et al.	Lärmmedizinisches Gutachten. DA- Erweiterung Hamburg	1999	D
Oeser, Beckers (Hrsg)	Bundesvereinigung Fluglärm: Fluglärm 2000	1999	D
Vallet et.al.	Noise and Epidemiological study of health effects : a feasibility study	1999	F
Maschke, Hecht	Gutachterliche Stellungnahme zu den medizinischen Gutachten M8 und M9. Ausbau Flughafen Schönefeld	2000	D
Ortscheid, Wende, H	Fluglärmwirkungen	2000	D
RIVM,	Nationale Milieuverkenning 2000-2030	2000	NL
RIVM	Milieubalans 2000. Het Nederlandsa milieu verklaad	2000	NL

Table 8: Literature from Central Europe on annoyance

AUTHOR	TITLE	YEAR	COUNTRY
Schümer-Köhrs + Schümer	DFG-Forschungsbericht Fluglärmwirkungen	1974	D
Francois, J	Aircraft Noise, Annoyance and Personal Characteristics	1978	F
Eidgenössischen Kommission für die Beurteilung von Lärm-Immissionsgrenzwerten	Teilberichte 1-5 (Straßenlärm 1979, Zivile Schießanlagen 1980, Kleinaviatik 1981, Eisenbahnlärm 1982, Militärflugplätze 1989).	1979-1989	CH
Fidell, S	A modern psychophysical procedure for assessing noise-induced annoyance	1980	USA
Fastl, H	Loudness and annoyance of sounds: subjective evaluation and data from Isa 532 B	1985	D
Kastka, J	Fluglärmwirkungen und Probleme ihrer Erfassung	1987	D
Kastka. J., E. Borsch-Galetke Guski R et al.	Longitudinal Study on Aircraft Noise effects at Düsseldorf Airport 1981 –1993	1995	D
Kaska et al.	Longitudinal study on aircraft noise	1995	D
Oliva, C	Belastung und Betroffenheit der Wohnbevölkerung Durch Flug- und Strassenlärm in der Umgebubg der internationalen Flughäfen der Schweiz	1995	CH
Bundesamt für Umwelt, Wald und Landschaft (Hrsg.):	Schriftenreihe Umwelt Nr. 296: Belastungsgrenzwerte für den Lärm der Landesflughäfen, 6. Teilbericht der Eidgenössischen Kommission von Lärm-Immissionsgrenzwerte	1998	CH
Kastka. J. u. M. Faust	Vorhersage von Belästigungsreaktionen auf Fluglärm durch Pegel Überschreitungshäufigkeitsmasse	1998	D
Möhler et al.	Vergleichende Untersuchung über die Lärmwirkung bei Straßen- und Schienenverkehr	2000	D
Bundesamt für Umwelt, Wald und Landschaft (Hrsg.):	Schriftenreihe Umwelt Nr. 318: Akzeptanz von baulichen Lärmschutzmaßnahmen	2000	CH

2.2.2 Questionnaires

The questionnaires were sent to scientists, authorities and citizen-initiatives in every European country. The initial selection of suitable experts was not as simple as anticipated (finding contact partners or addresses). Initially many people/institutes were asked about their willingness to participate in a questionnaire on noise effects in their country/region. Many of them refused on the grounds that they were not experts in this field. Around 60 people/institutes were questioned which ultimately resulted in 37 questionnaires being sent out of which 11 have so far been completed and returned..

In order to increase the return quota of completed questionnaires, telephone calls were made on a weekly basis (up to four calls per person/institute). This resulted in the knowledge that the necessary time for filling in the questionnaires was greater than expected. Many scientists have so many other appointments that they have no time left for such tasks as filling in a questionnaire. On the other hand, particularly in the smaller countries it was difficult to find noise experts, authorities and citizen-initiatives with the exception of the Netherlands .

We would like to thank all experts who took the time to complete our questionnaire

In Table 9 the ratio of questionnaires sent and returned is shown on the basis of the individual European countries.

Table 9: Replies from questionnaires sent out to Central European Experts

COUNTRY	SENT	RETURNED
Germany	4	3
United Kingdom	6	2
Netherlands	4	2
France	6	1
Austria	3	1
Switzerland	3	2
Ireland	3	-
Belgium	4	-
Luxembourg	4	-

2.3 Epidemiologic data on traffic noise pollution in Northern European Countries

2.3.1 General Information

Noise is a relatively small academic theme in the majority of countries around the Baltic sea. Only four cities exist with more than 1 million people (St Petersburg, Riga, Stockholm and Copenhagen). Russia excluded, the area is some 1,7 million km^2, 5-6 times the size of Germany and 3-4 times that of Spain. The total population is approximately 30 million. This figure includes Sweden, Denmark, Norway, Finland, Iceland, Estonia, Latvia, Lithuania and Kaliningrad Oblast. In all, some 17 persons live in each km^2. There are therefore two main reasons for low academic involvement in the study of noise:

Only a few areas suffer from noise problems

Eastern countries have paid little attention to the noise issue

An odd issue, from a European perspective, is that of different noise resistance and reactions in relation to the time of year in question. Few academic papers, if any, are written on this phenomena. Some comments are offered later in this report.

2.3.2 Data collection for Northern Europe

Denmark has very limited national noise research. They use results from other countries and implement them accordingly.

Norway carries out some noise research.

Finland carries out some noise research.

Sweden carries out some noise research and to some extent coordinates the Nordic mutual R&D.

The questionnaires for this project have been discussed in a Nordic forum and therefore replied in a mutual fashion. Therefore, all four Nordic countries are reported with equal land experience.

One telephone interview was carried out with the Baltic states, by a well informed Lithuanian – Canadian aid environment worker in Vilnius. As no Baltic research is mentioned, no limits are written and the replies have been given unofficially. Therefore, we have not been allowed to reference an individual or an organisation for the information gathered. We have only been given permission to mention the University of Vilnius. The objective of Lithuanian, and most likely all-Baltic states, is to adopt European legislation during negotiations on EU membership.

2.3.3 Noise-induced sleep disturbance

75 percent of all noise-induced sleep disturbance is related to road traffic. 23 percent is related to rail and air and 2 percent to other traffic related sources such as work machines, harbours etc.

Swedish, Norwegian, Finnish and also Danish homes are well insulated from the point of view of climate. The use of multi-glass windows is included in the national energy efficiency policies. The level of insulation in walls and roofs has the same positive impact on keeping noise outside the home.

Major Nordic cooperation has been implemented in this area to identify at what levels and at what times citizens need their silence. The link to vibrations is clear. The use of heavy vehicles in narrow and old town environments are closely linked. In the city of Lund, 12 meter diesel buses have been banned in favour of natural gas buses. With a 10 litre spark ignited and lower compression engine, the noise related vibrations are reduced to levels that are acceptable even during the night.

Homes and businesses have been moved to remote areas, distanced from major road constructions, to avoid related noise disturbances. Homes affected by traffic noise have a tendency to fall in price at a faster rate in sparsely populated areas than those in high density areas. The reason is that there are more options on the market due to the fact that road noise impacts fewer homes than in Europe in general.

Leq and Lmax levels from the Nordic replies relate to EU norms rather than to local research results. SEL is not used as a yardstick.

2.3.4 Vegetative Hormonal Reactions

The Nordic countries do not conduct research in this area. However, one study has previously been conducted related to sleep disturbances during sleep periods. Irregular heart frequency has been identified when the main factor is repeated irregular noise disturbances. The vegetative hormonal reactions are not easy to establish, but there seems to be a link between other disturbance and reaction during sleep. Such reactions can be illness, other means of stress during the day such as lack of harmony at work, in the family, over own economy etc.

There is no Nordic literature to refer to in this case.

2.3.5 Annoyance

Annoyance is the second most investigated issue and is related mainly to road traffic noise. Major airports are few in number and are located in sparsely populated areas. Air and rail noise is present where signs of life and business prevail rather than being a disturbance.

Literature available points to the fact that the definition of annoyance varies in different regions and also between seasons. Northern Europe has continuous daylight for weeks and months in the summer time, while daylight does not occur for weeks and months in the winter time. Some 1,5 - 2 million people near (500-1000 km south) and north of the arctic circle live in these conditions. Literature is rare in this respect and the information gathered has been obtained through unscientific interviews.

Winter

After working hours, annoyance occurs after 20.00 hrs from traffic, barking dogs, trains etc. Silence is simply to be expected in northern Europe. Packed snow on the roads helps in keeping any road annoyance levels down. In snowy areas, everything is less noisy.

Summer

With daylight, people restore that which has been lost during the dark winter time. Eating on the terrace invites activities with family, friends and neighbours. People are expected to travel and the sound of aircraft, trains and traffic can continue to well after 22.00, even to 23.00 without being troublesome to families.

Annoyance is to some degree related to expectancy., Nordic citizens do not seem to accept any kind of noise over a 65 – 68 dBA level. Scientists are currently investigating whether or not the suggested EU levels, limits and time definitions fit with the time table of a common Nordic citizen. They will obviously not fit with the population situated in the most northern parts of the region.

2.3.6 Questionnaire distribution

Prior to sending out the questionnaires, a major investigation was carried out on who would be the most appropriate representatives to respond from each country. The questionnaires were therefore distributed as follows:

Sweden	4
Denmark	2
Norway	4
Finland	2
Iceland	1
Estonia	5
Latvia	9
Lithuania	2
Total	**29**

None of the Baltic states have responded in writing (as expected). Iceland's response has referred to Danish results and the questionnaire has been discussed in a Nordic forum, where two scientists were asked to reply on everybody's behalf.

2.3.7 The Baltic states

Plan economy has not taken the same considerations for the needs of the citizens of the Baltic states as in the rest of Europe. Roads, air fields and rail constructions have been built in areas where it is less expensive to build. Therefore, roads pass through densely populated areas. Rail and switchyards are located in populated cities leading to major noise disturbances.

- Acceleration
- Heavy duty traffic in cities
- Switchyard rail-to-wheel squeak
- Tire and wind friction noise

are among the most frequently mentioned noise factors among scientists from the Baltic States.

The arrival of western aid-workers in Baltic environmental offices has introduced the socio-economic effect parameter of how much disturbance and pollution hinders work to be done. North American suggestions produce solutions for major roads outside the cities while European suggestions for the Baltic cities suggest combination of public transportation and external road solutions.

2.3.8 Socio-economic effects

In comparison to the lack of Nordic R&D, there is much being done to prevent annoyance, sleep disturbance and other negative noise related functions mainly from traffic, in society. Noise walls, de-routing of traffic and in particular socio-economic research on the effects on property pricing, lack of work capacity due to noise disturbance, etc. is being carried out.

When assuming that a normal highway, which needs to be up-graded from two to four lanes and a speed limit increased from 70 km/h to 110 km/h, the issues addressed by this research are:

- How many homes will have increased noise problems
- How much will each home be affected
- How much will the price of the homes be affected in terms of overall value
- Who and how should bear the costs?

In most cases society does not take any responsibility for the result of societal needs. Individuals thereby pay for the need for society to expand, be more efficient and earn more. To some extent, this policy, (the lack of societal reimbursement for loss of value), can be looked upon as extra taxation for private individuals, i.e. an extra tax upon the disturbances produced by the new infrastructure itself.

The newly built bridge between Malmö and Copenhagen has demanded an increase of train capacity from the Malmö Central Station to the foot of the bridge. During the day, a train passes a school every 6 minutes, hindering education to a degree where the capacity of learning is not fully utilised.

3 Evaluation of the existing data pool

3.1 Objectives

3.1.1 Literature enquiry

At the Technical University of Berlin, an online literature search in international databases was carried out, in order to retrieve publications relevant to the project.

Four groups of keywords were applied:

Group I: Annoyance "AND" noise or traffic noise (car, train, aeroplane)

Group II Sleep or health effects or sleep disturbance "AND" noise or traffic noise (car, train, aeroplane)

Group III: Vegetative hormonal reactions or blood pressure or heart frequency or stress hormones "AND" noise or traffic noise (car, train, aeroplane)

Group IV: Cross cultural comparisons "AND" noise or traffic noise (car, train, aeroplane)

Since there are methodological differences, particularly in older studies, from methods currently in use, only papers published after 1990 were included in the study.

When taking into account the relative rarity of papers published on cross cultural differences we also included papers referring to this subject published since 1985.

Certain papers judged as being of special importance, were also included in the study, even if their date of publication lay outside the limits given above. The data bases searched included:

For items I, II, III: as of 1990 in the Medline data base (medical data base) as of 1992 in the data bases:
Environline (environmental data base)
TEMA (technology and management data base)
SOLIS (social scientific data base)
PSYNDEX (psychological data base)

For item IV: as of 1985 cross cultural studies in all data bases of the German Institute for Medical Documentation and Information (DIMDI) and Environline (environmental database).

3.1.2 Selection criteria

To adequately compare studies retrieved from the databases, the following restrictions were placed on the literature analysis:

Only primary studies adequately detailed in their descriptions were compared.

In the publications on the topic of annoyance by noise, authors were chosen who examined "annoyance" in all studies, for the purpose of comparability (the same terminology).

The sound level should be uniformly described in $L_{eq\ 24h}$. Studies on the impairment of night sleep should be described in $L_{eq\ 8h}$. Wherever possible the levels cited in the paper were converted to $L_{eq\ 24h}$ or $L_{eq\ 8h}$ [1].

3.2 Methods

The data from the selected studies are presented by dose-response-curves. For this, the relative number of highly annoyed persons is measured in relation to the equivalent duration noise level (Equivalent continuous sound level) in dB (A). Since the Schultz paper [Schultz, 1978] it is internationally accepted that the criterion for "strong" (or "considerable") annoyance stands at about

[1] The details for the conversions of sound levels, which was taken, was given in different publications (For details see annex).

70% of the scale, this means "highly annoyed" describes those persons who have chosen the values in the upper 30% of the original scale.

The data from the publications was found to bear greatly differing scales. In order to make the desired comparison, the top 30% of the annoyed persons from each study were taken as "highly annoyed".

In the publications, "group mean average" values were indicated rather than "original values". Provided that the number of persons in these groups is known, a correct dose response curve can be determined by a weighting of the group mean average with the group number by regression. The deviation of the data points of the dose response curve is however dependent on the aggregation (The dose-response-curve describes the mean average values better, the more values are summarized by a mean average value). Statistical testing is not useful when aggregation values differ.

As previous studies show, for example UBA, 1990, the dose-response-curves rise excessively with the equivalent continuous sound level and then level off at higher values. Therefore the dose-response-curves were approximated by an exponential or polynomial function of the annoyance values in question. The approximation, which best determines the data points of each region in question (greatest R^2) is taken as the dose-response-curve (maximum likelihood decision). The factor R^2 shows the coherence between the published mean average values and the fitted curve.

3.3 Results

In the next chapter, the results of the Northern, Central and Southern European studies will be briefly introduced, from which the data for the dose-response-curves for annoyance and sleep disturbance was collected.

The studies which were suitable for the comparison were consulted for noise-annoyance. See segment (literature enquiry / selection criteria) on the selection criteria.

Since the annoyance reactions to flight noise and traffic noise are different, see e.g. Kryter [1982], the studies on these two noise sources were treated separately.

3.3.1 Annoyance by traffic noise

Northern Europe

- **"Road traffic noise annoyance in relation to the individual noise dose"** [Björkman, M. et al., 1998] 60 -178 persons (in 15 different areas) were interviewed on various subjects, including noise pollution. The degree of annoyance in each of the surveyed persons was measured on a five stage scale ranging from "does not notice" to "very annoyed". An equivalent continuous sound level over 24 hours as well as maximal levels was measured. For the calculation of the 30% of "highly annoyed" persons, the stages "notice noise but not annoyed" and "does not notice" were combined into one group. The 30% value is not quite reached even at a four-stage scale and the share of "highly annoyed" is therefore a little underestimated.

- **"The combined effects of road traffic implications for environmental guidelines"** [Klaeboe, R., 1998] In 1987, 1994 and 1998 interviews were carried out with approx. 1000 persons, each in a centrally located district of Oslo (with a low quality standard of life). Among other things the participants were asked about their individual noise annoyance. The $L_{Aeq,\ 24h}$ was calculated for the apartment side with the highest level of noise exposure (using the Nordic Method for calculating road traffic noise).

The data from the Northern countries about annoyance by traffic noise are shown in Fig. 4.

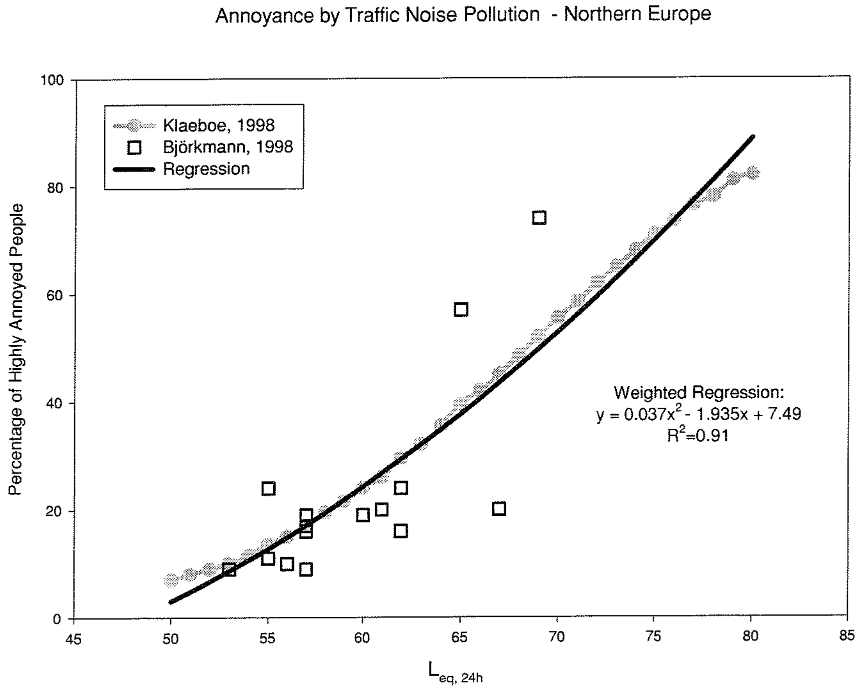


Fig. 4: Percentage of people highly annoyed by traffic noise as a function of energy equivalent continuous sound level. The figure shows the results of two studies in Northern Europe together with the polynomial fit of the weighted data.

Central Europe

- "**Road traffic noise annoyance in Amsterdam**" [Meijer, H.; Knipschild, P. u. Sallé, H., 1985] This study took place within an investigation on heart conditions. 3445 persons between the ages of 41 and 43 living in Amsterdam were examined about risk factors for coronary heart disease, a part of the examination also concerned environmental noise. The equivalent continuous sound level was measured between 10.00am and 4.00pm. The calculation of $L_{eq,24h}$ was made by method 1 (see annex). The study shows that persons with sleep disturbances had higher annoyance reactions than those who's sleep was not impaired by noise.

- "**Die Wahrnehmung der Verkehrslärmemissionen im Kanton Basel-Stadt im Vergleich zu den erhobenen Lärmmesswerten**" [Conzelmann-Auer, C. et al., 1993] The examination was part of the Basel air pollution study. 1033 families with children under 5 years of age were questioned about various social demographic indicators as well as the degree of the subjective annoyance by traffic noise (11-stage thermometer scale). The sound level was calculated with a model, and sample measurements were verified. The calculation from $L_{eq,16h}$ to $L_{eq,24h}$ was done with method 2 (see annex). The noise pollution varied greatly in level ranges. As a result a dose-response-curve was published.

- "**Die Abhängigkeit der Schallbewertung vom Geräuschkontext**" [Oliva, C. u. Hüttenmoser, C., 2000] 2052 residents in the environment of airports Geneva-Cointrin and Zurich were interviewed for the annoyance by traffic noise and aircraft noise. An 11-stage thermometer scale was used for it. The noise pollution was measured separately for traffic and air traffic at representative points in front of each of the houses (L_{eq} $_{16h}$). The value was calculated to$L_{eq,24h}$. (method 2 (see annex)).

The data from the Central countries concerning annoyance by traffic noise are shown in Fig. 5.

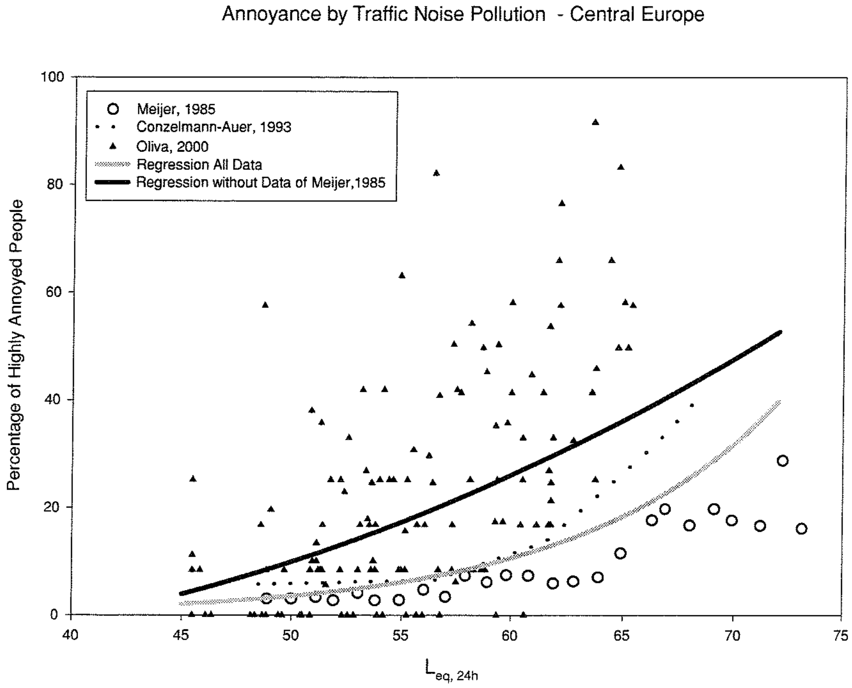


Fig. 5: Percentage of people highly annoyed by traffic noise as a function of energy equivalent continuous sound level. The figure shows the results of three studies in Central Europe together with the regression line of all weighted data, and a second regression line excluding the data of the study of Meijer et. al, 1985.

Southern Europe

- **"A Social Survey on the Effects of Environmental Noise on the Residents of Pamplona, Spain"** [Arana,M. u. Garcia,A. 1998] Altogether 496 persons were questioned in writing about their individual attitudes to the noise problems of the town in five fields of Pamplona. In representative areas noise measurements were carried out in the fields ($L_{Aeq,\ 24h}$). The degree of annoyance was measured on a five-stage scale. For the calculation of the highly annoyed persons, half of the penultimate stage was added to the last stage on the scale. In the publication, mean average values were published.

- **"Community response to environmental noise in Valencia"** [Garcia, A. et al., 1990] The study was carried out in 5 fields in Valencia with both high and low levels of traffic noise and a field with predominantly leisure-noise at the weekends. In 263 of the interviews, the individual degree of the annoyance was determined by a 5-stage scale. On five successive days, the $L_{Aeq,\ 24h}$, on the front side of the buildings was measured. Again, for the calculation of the highly annoyed persons half of the penultimate stage was added to the last stage on the scale.

- **"Subjective Annoyance Caused by Environmental Noise"** [Aparicio-Ramon, D.V., 1993] 215 persons were questioned in writing among other things about the noise pollution in Natzaret (Spain, 7742 inhabitants). The noise pollution was measured by a 4-stage scale. For the monitoring the sound level a grid with 45 test points was used which covered the municipal area. The measurements were carried out exclusively on working days. The level given in this paper was converted using the help of measurements parameters taken from two Berlin streets (method 1, see annex). The values of the uppermost category with 20% of the second highest category were added together in order to create the category of the "highly annoyed".

The data from the Southern countries concerning annoyance by traffic noise are shown in Fig. 6.

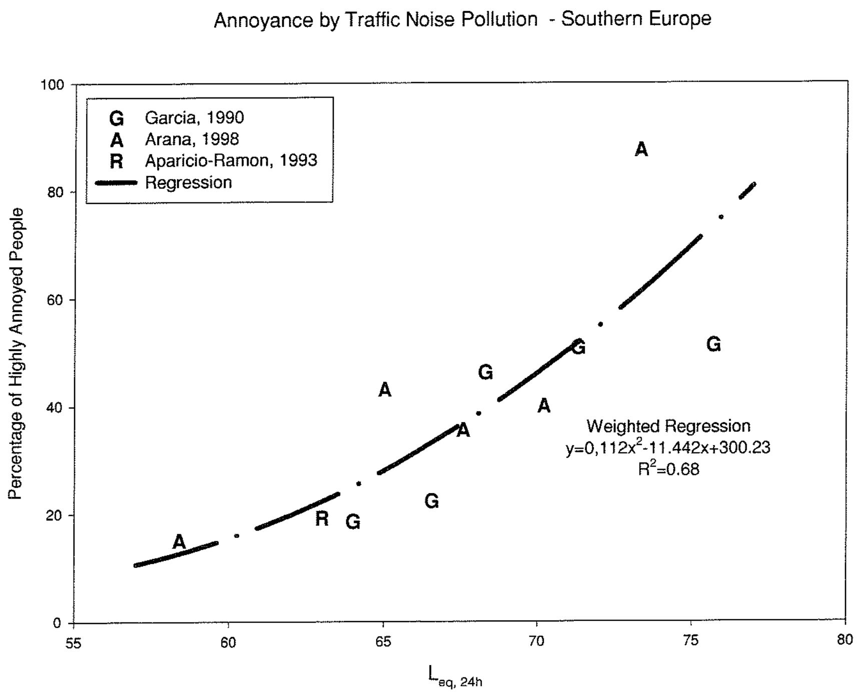


Fig. 6: Percentage of people highly annoyed by traffic noise as a function of energy equivalent continuous sound level. The figure shows the results of three studies in Southern Europe together with the polynomial fit of the weighted data

Comparison of the dose-response-curves

In order to compare the annoyance reactions of the countries provoked by traffic noise between North, Central and Southern Europe, the respective dose response curves are depicted together in Fig. 7.

The results of the Dutch study of Meijer, Knipschild a. Sallé, [1985] were considerably different to the other two Central European Studies from Switzerland. Why the results of this study differed so strikingly from the other Central European studies is unclear, since a validity analysis of single studies was not possible within the context of this work.

However, it can be assumed that methodical or local differences may have led to the strongly divergent data.

The dose-response-curves for Central Europe, excluding the results of Meijer, Knipschild a. Sallé [1985], showed the maximum likelihood fitted by a polynomial trend line. That was also the case for data from the Northern and Southern Europe regions. The polynomial trend line represents the Northern European data quite accurately, while for the Southern European data this approximation proved to be slightly less precise.

Fig. 7 shows the dose-response-curves for Northern, Central and Southern Europe (Annoyance by traffic noise).

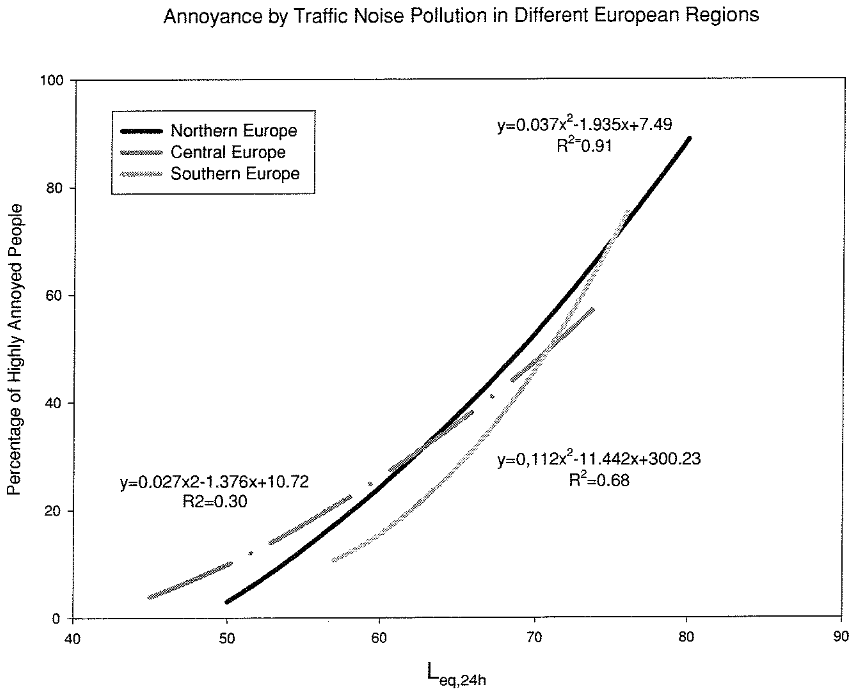


Fig. 7: Comparison of dose response curves of annoyance by traffic noise from Northern, Central and Southern Europe. The lines shown in this figure are identical with the regression lines shown in Fig. 4 and Fig. 5. For Central Europe the line represents the data excluding the study of Meijer et. al, 1985.

Regarding the polynomial fit to the Central European data (without Meijer, Knipschild a. Sallé [1985]), certain differences to the other regions became obvious.

Table 10: Values for selected percentages of highly annoyed by traffic noise (without Meijer-Knippschild)

	Northern Europe	Central Europe	Southern Europe
R2	0,9115	0,2997	0,6823
15% highly annoyed	56 dB(A)	53 dB(A)	60 dB(A)
25% highly annoyed	60 dB(A)	54 dB(A)	64 dB(A)
40% highly annoyed	66 dB(A)	68 dB(A)	68,5 dB(A)

In conclusion, a lower annoyance reaction of people surveyed in Southern Europe compared to Northern and Central European people is observed. There is, however, a sharp increase in the percentage of highly annoyed people in Southern Europe by sound levels up to 75 dB(A), not observable by the data from Northern and Central Europe.

Excluding the study from the Netherlands [Meijer, Knipschild, Sallé, 1985] there exists a higher percentage of highly annoyed persons in the Central Europe results. At low sound levels the percentage of highly annoyed persons was higher than the other regions, however, the dose-response curve rises more slowly at greater levels.

It should be noted that data for Northern Europe comes from two countries (Norway and Sweden) while the South European data was collected only in Spain and the source of the Central Europe data comes only from Switzerland, when the Dutch study is excluded. Therefore the conclusions may not be representative. With the results available it could be shown, however, that differences regarding the annoyance reaction between the individual countries by traffic noise probably exist.

3.3.2 Annoyance by aircraft noise

Northern Europe

- "**Area of noise survey around Oslo airport Fornebu**" [Gjestland, T. et al., 1990] Residents in the same district as the largest Norwegian airport were questioned by phone about aircraft noise. Interviews were carried out before an increase in air traffic noise and again 4 months later. The sound level was calculated and checked with measurements. For the FBN (a Norwegian aircraft noise index) the formula L_{dn} = EFN – 0,8 dB was used. The L_{eq},24h were calculated with the formula L_{eq},24h = EFN – 2,8 dB.

The data from the Northern countries concerning annoyance by aircraft are shown in Fig. 8.

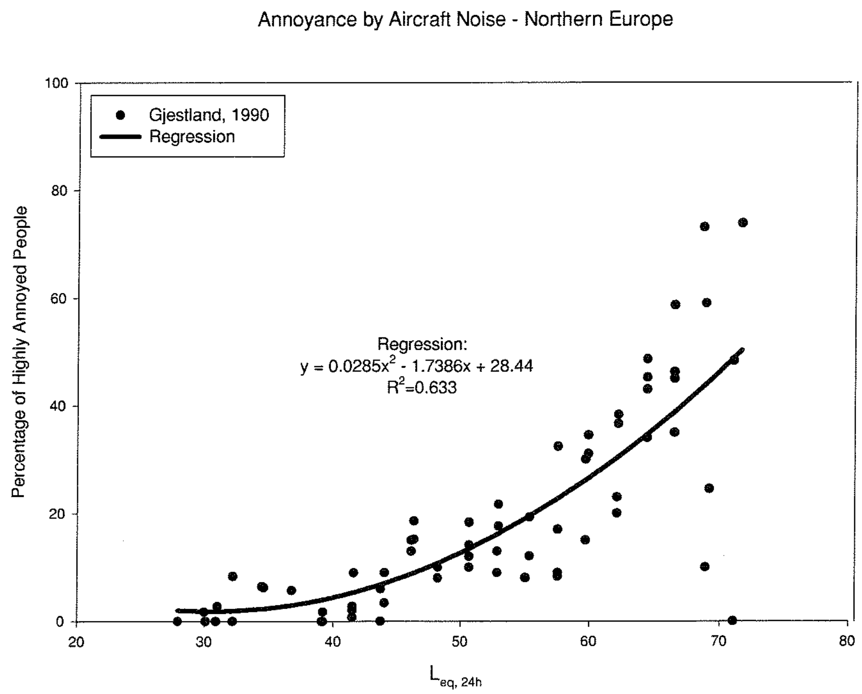


Fig. 8: Percentage of people highly annoyed by aircraft noise as a function of energy equivalent continuous sound level. The figure shows the results of one study in Northern Europe together with the polynomial fit of the weighted data.

Central Europe

- "***Response functions for environmental noise in residential areas***" [Miedema, 1993] In the project, the influence of air traffic noise as well as other noise pollution was measured. For this a total of 1758 persons were questioned in France (Paris-Orly), in the Netherlands (Amsterdam-Schiphol) and Great Britain (Glasgow airport). The most frequently mentioned source of noise besides the air traffic was the traffic noise. The sound level was measured and calculated ($L_{eq,24h}$).

- "**Die Abhängigkeit der Schallbewertung vom Geräuschkontext**" [Oliva U. Hüttenmoser, 2000] 2052 residents were interviewed regarding their annoyance from traffic noise and aircraft noise in the surrounding area of the Geneva-Cointrin and Zurich airports. An 11-stage thermometer scale was used. The traffic and air traffic noise pollution were measured separately at specific points in front of each of the houses ($L_{eq,16h}$). For a comparison with other studies the $L_{eq,16h}$ and the $L_{eq,18h}$ was converted to $L_{eq,24h}$ (method 2 see annex) It should be noted that the representation in this paper does not correspond to the original analysis which was carried out by Oliva et al. in 1993.

- **"Untersuchungen zum Lärmkontingenzkonzept: Akzeptanz, Belästigungsverhalten und Meinungsbild am Beispiel des Düsseldorfer Flughafens 1987-1995"** [Kastka et al., 1996]: 1250 residents were questioned, among other things, about the annoyance caused by aircraft noise in the years 1987 and 1995 in Ratingen on the eastern side of Düsseldorf airport. The flight noise pollution was, calculated on the one hand by an acoustical model and measured on the other for periods of 16 or 18 hours ($L_{eq,16h}$ und $L_{eq,18h}$). The estimate of the $L_{eq,24h}$ was calculated according to DIN 45 643 part 1 (method 4 see annex).

- **"Evaluation of Noise Exposure and Annoyance around Brussels Airport: Energy Descriptor versus Exceedance- Duration Descriptor"** [Jonckheere, R. E., 1989] In total 677 persons were questioned from 11 different areas around Brussels airport. The noise levels of these 11 points were measured and the surveyed persons were asked about their annoyance. The annoyance was measured on a 3-stage scale. Different objective noise pollution indexes were measured. The given NNI was converted with a published cover formula to L_{dn} and then to $L_{eq,24h}$ (method 4, see annex). The data from the Central countries concerning annoyance by aircraft are shown in Fig. 9.

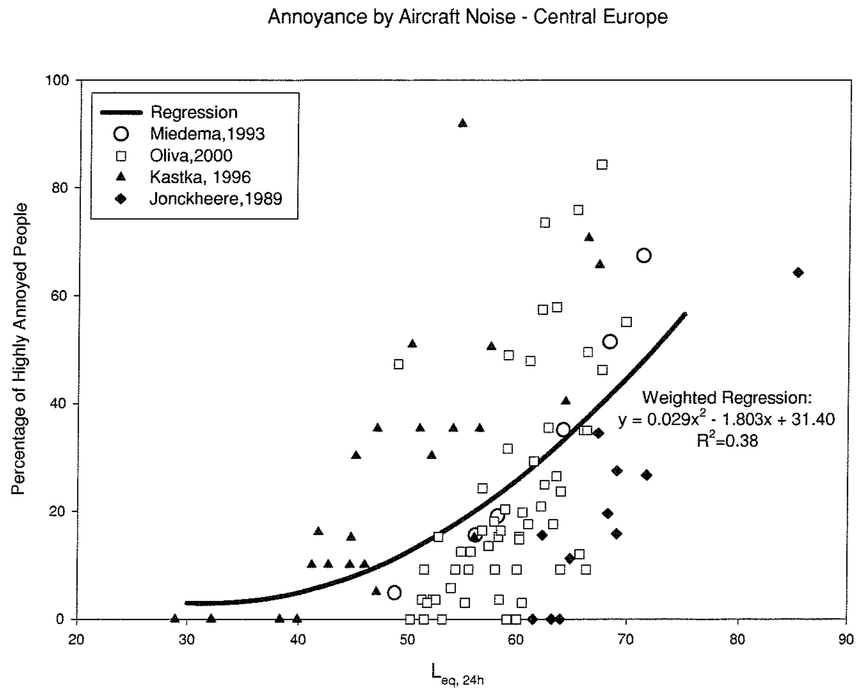


Fig. 9: Percentage of people highly annoyed by aircraft noise as a function of energy equivalent continuous sound level. The figure shows the results of four studies in Central Europe together with the regression line of all weighted data

Southern Europe

- **The community response to aircraft noise around six Spanish airports"** [Garcia and Faus, 1993] 1800 persons were interviewed in the surrounding areas of six Spanish airports (Madrid, Palma, Barcelona, Valencia, Sevilla and Zaragoza). The annoyance by aircraft noise was measured on a 5-stage scale (not, little, moderately, rather and very). The flight noise pollution was taken from a model (Federal Aviation Administration 1982, Integrated Noise Model)(method 4, see annex).

The data from the Southern countries concerning annoyance by aircraft are shown in Fig. 10.

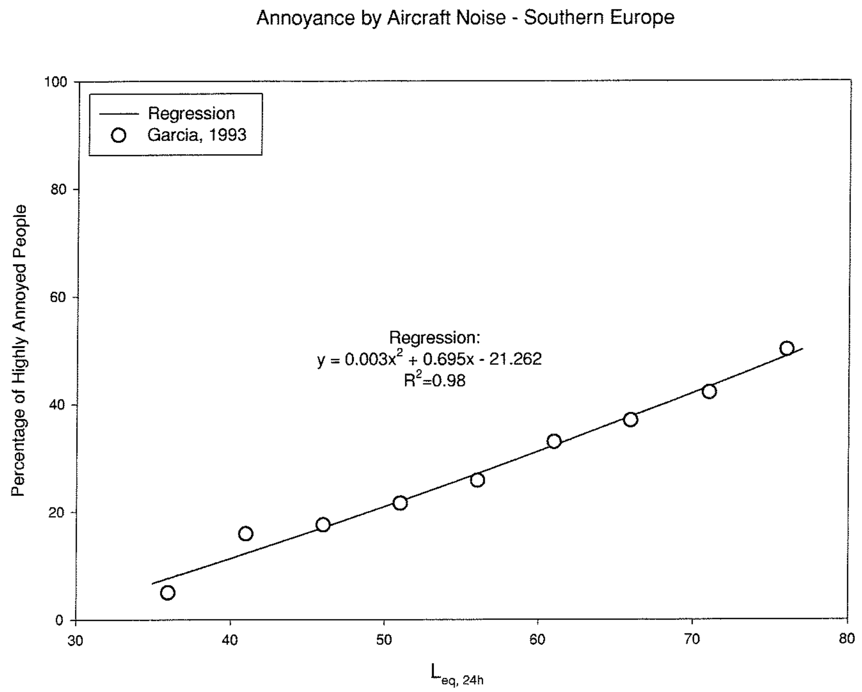


Fig. 10: Percentage of people highly annoyed by aircraft noise as a function of energy equivalent continuous sound level. The figure shows the results of one study in Southern Europe together with the polynomial fit of the weighted data

Fig. 11 shows the dose-response-curves for Northern, Central and Southern Europe (Annoyance by aircraft noise).

Table 11: Sound levels for selected percentages of highly annoyed persons by aircraft noise

	Northern Europe	Central Europe	Southern Europe
R^2	0,6311	0,3803	0,9842
15% highly annoyed	52 dB(A)	53 dB(A)	44 dB(A)
25% highly annoyed	59 dB(A)	60 dB(A)	54 dB(A)
40% highly annoyed	67 dB(A)	68 dB(A)	68 dB(A)

The results indicate that no essential difference exist in the annoyance reaction to aircraft noise between North and Central Europe. The results from Southern Europe, however, clearly deviate. At lower levels, more of the people surveyed from Southern Europe felt strongly annoyed than people in North and Central Europe. South Europeans felt less frequently annoyed as those people asked from the Northern and Central Europe countries at higher levels (after 66 dB (A)). Due to the data pool mentioned above, however, further examinations would be desirable. A coordinated study of the different European regions could deliver data confirming or disproving the differences extracted from the existing literature.

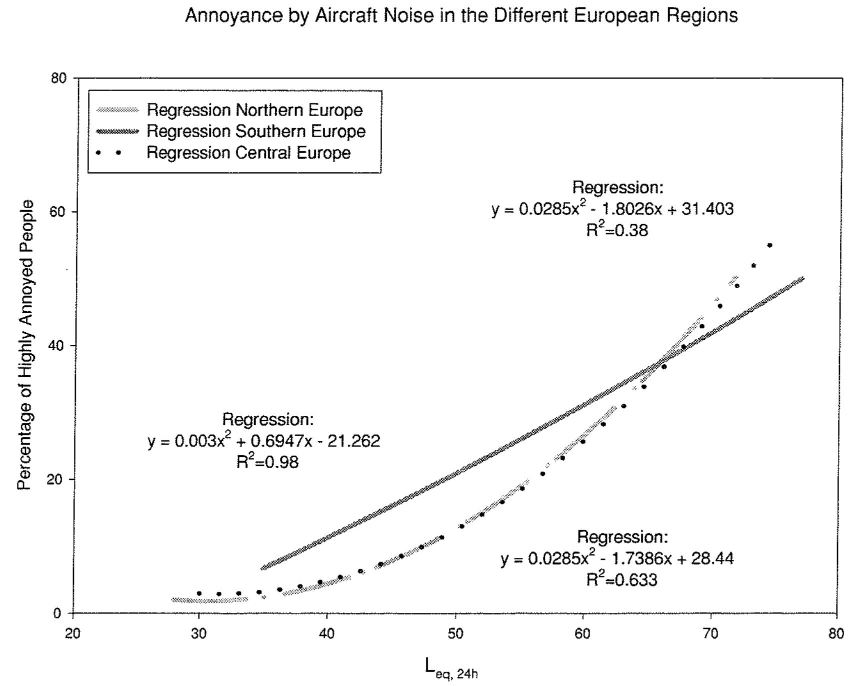


Fig. 11: Comparison of dose response curves of annoyance by aircraft noise of Northern, Central and Southern Europe. The lines shown in this figure are identical with the regression lines shown in Fig. 8, Fig. 9 and Fig. 10.

3.3.3 Comparison of the studies for the sleep disturbance

At first, an examination was made, to find out whether the following studies showed common parameters. The following study references are related to the numbers in Table 12 and Table 13

Study No. 1. Belojevic, G.; Jakovljevic, B. u. Aleksic, O. (1997): Subjective reactions to traffic noise with regard to some personality traits, Environmental International, 23(2), S.221-226

Study No. 2. Garcia, A. u. Romero, J. (1987): Road traffic noise and sleep disturbance, In: National Conference on Noise-Control-Engineering, NOISE-CON '87, Noise Control Foundation Poughkeepsie, NY (USA), S. 461-464

Study No. 3. Griefahn, B. (1986): Grenzwerte nächtlicher Belastbarkeit durch Straßengeräusche, Applied Acoustics 19, S. 265-284

Study No. 4. Horne, J.A.; Pankhust, F.L.; Reyner, L.A.; Hume, K.; Diamond, I.D. (1994) : A Field Study of Sleep Disturbance: Effects of Aircraft Noise and Other Factors on 5,742 Nights of Actimetrically Monitored Sleep in a Large Subject Sample, Sleep 17(2), S. 146-159

Study No. 5. Jürriens et al. (1983) : An essay in European research collaboration, common results from the project on traffic noise and sleep in the home, in: Griefahn, B. (1991) : Verkehrslärm – psychosoziale und vegetative Wirkungen, Schlafstörungen, Forum Städte-Hygiene, 42, S. 276-283

Study No. 6. Libert, J.P.; Bach,V.; Johnson, L.C.; Erhart, J.; Wittersheim, G.; Keller, D.(1991): Relative and Combined Effects of Heat and Noise Exposure on Sleep in Humans, Sleep 14(1), S. 24-31

Study No. 7. Maschke, C. et al. (1992) : Der Einfluss von Nachtfluglärm auf den Schlaf und die Katecholaminausscheidung, Schr.-Reihe des Vereins Wasser-,Boden- und Lufthygiene 88, S. 395-401

Study No. 8. Öhrström, E.; Björkman, M. u. Rylander, R.(1990): Effects of noise during sleep with reference to noise sensitivity and habituation, Envrionmental International, 16, S. 477-482

Study No. 9. Öhrström, E., Agge, A. u. Björkman, M., 1998: Sleep disturbances before and after reduction in road traffic noise, In: 7th int. Congress on Noise as a Public Health Problem – Noise Effects'98, Congress Proceedings V.2, 451-454

Study No. 10. Öhrström, E. (1995): Effects of low levels of road traffic noise during the night: a laboratory study on number of events, maximum noise levels and noise sensitivity, Journal of Sound and Vibration, 179(4), S. 603-615

Study No. 11. Ollerhead, J. B. u. Jones, C. J. (1993): Aircraft noise and sleep disturbance: a UK field study, In: Noise as a Public Health Problem, V.3, S. 353-358

Study No. 12. Vallet, M. u. Vernet, I. (1992) : Nachfluglärmindex und Ergebnisse der Schlafforschung, Schr.-Reihe des Vereins Wasser-, Boden- und Lufthygiene 88, S. 409-412

Study No. 13. Van, F.; Hume, K.I. u. Watson, A. (1993): EEG responses to aircraft noise in „noise-sensitive" and „less noise-sensitive" subjects, Noise as a Public Health Problem, 2, S. 569-572

Study No. 14. Aparicio-Ramon, D.V.; Morales Suarez-Varela, M.; Garcia, A.G.; Llopis Gonzalez, A.; Ruano, L.; Sanchez, A.M.; Ferrer Caraco, E.(1993): Subjektive Annoyance caused by Environmental Noise, J. of Env. Pathology, Toxicology and Oncology, 12(4), S. 237-243

Study No. 15. Arana, M. u. Garcia, A. (1998): A Social Survey on the Effects of Environmental Noise on the Residents of Pamplona, Spain, Applied Acoustics, V. 53, N. 4, S. 245-253

Study No. 16. Garcia, A. ; Miralles, J.L. ; Garcia, A.M.; Sempere, M.C. (1990): Community Response to Environmental Noise in Valencia, Environment International, 16, S. 533-541

For single sleep disturbance indicators, a comparison was possible between North, Central and Southern Europe.

Table 12 shows the parameters examined in the traffic noise studies.

Table 12: Examination parameters of the studies of sleep disturbance through traffic noise

	North Europe			Central Europe				South Europe			
Study No.	10	8	9	6	5	3	2	1	14	15	16
Complete sleep duration				+				+			
Duration/number of light sleep				+							
Duration of the REM sleep					+	+					
Number of sleep stage changes				+							
Heart frequency		+			+						
Sleep stage changes				+							
Body movements	+	+	+								
Waking up reactions objective				+	+						
Waking up reactions subjective	+	+	+	+		+	+	+		+	
Subjective falling asleep duration	+	+	+	+		+		+			
Falling asleep difficulties	+	+	+				+	+	+		+
Subjective sleep quality	+	+		+	+	+		+			
Achievement	+	+			+						
Tiredness during the day	+	+	+					+			
Atmosphere	+	+	+								

Objective data on sleep disturbance was described in the North and Central European studies, but the data was not adequate to form a comparison these two European regions. Only the subjective data could be used for comparison in the following way. Two studies from Central Europe 3 [Griefahn, B.

1986] and 6 [Libert, J.P. et al. 1991] were excluded because they could not be converted into a dose-response-curve.

The given data, referring to aircraft noise, is represented in Table 13.

Table 13: Examination parameter of the studies on sleep disturbance through Aircraft noise

	Central Europe				
Study No.	7	11	4	13	12
Complete sleep duration					
Duration/ number of the light sleep				+	
Duration of the REM sleep					
Duration of deep sleep					
Arousal reactions				+	
Vosoconstriction					
Heart frequency					
Sleep stage changes				+	
Body movements		+	+	+	
Stress hormones	+				
Waking up reactions objective					+
Waking up reactions		+	+		
Subjective falling asleep duration					
Falling asleep difficulties					
Subjective sleep quality			+	+	
Achievement					
Daytime tiredness					
Atmosphere					

Studies regarding sleep disturbances by aircraft noise were only available from Central Europe. Therefore no comparison with the other European regions was possible.

For a comparison on subjective awake data (by traffic noise) the following studies were considered:

Northern Europe

Study No. 8. **"Effects of noise during sleep with reference to noise sensitivity and habituation"** [Öhrström, E., Björkman, M. u. Rylander, R., 1990] In this publication, a field study and two laboratory studies are introduced. In the field study, verbal and written interviews were carried out regarding the sleep behaviour in two different areas suffering from noise pollution (69 persons) and one control area without noise pollution (37 persons). The interview surveyed difficulties in falling asleep, awakening reactions and sleep quality. The sound level was measured as L_{Aeq} and changed with the German recommendation RLS 90 to the night level L_{eq} (method 3). In the laboratory, studies were made of 24 persons (22-34 years old) who spent 14 nights in a sleep laboratory. 12 of the persons described themselves as sensitive to noise. Per night the participants were exposed to 57 sound events with a level of 58 -60 dB (A). During 4 of the nights, 28 persons were exposed to 50 or 60 dB (A) maximum levels (heavy freight vehicles). The number of individual sound events ranged from 4, 8, 16 to 64 per night. Conversions were carried out for the calculation of the nightly $L_{eq,8h}$ (method 3, see annex).

Study No. 9. **"Sleep disturbances before and after reduction in road traffic noise"** [Öhrström, E.; Agge, A.; Björkman, M. 1998] The study in Gothenburg was carried out among residents of a busy street. A main questionnaire implemented only once (142 persons) and a questionnaire implemented over a period of three days specific to sleep parameters (116 persons) were used. Interviews were instigated before and after the opening of a tunnel to reduce street traffic noise. The sound level was measured at 5 different positions around the residential buildings (gardens) during 3 to 4 days. The measured sound levels are the L_{Aeq} (24h, day 06-22h, night 22-06h), L01, L90, L_{Amax}.

Study No. 10. **"Effects of low levels of road traffic noise during the night: a laboratory study on the number of events, maximum noise levels and noise"** [Öhrström, E. 1995] In study 10 it is intermittent noise which impairs the sleep more strongly, rather than continuous traffic noise. For this reason the study was not included.

The percentages of persons from studies 8 and 9 subjectively woken up by the traffic noise are represented in a dose-response-curve. A polynomial regression curve has been fitted. For the calculation the data, points represent persons weighted after the number of people asked.

The data from the Northern countries on sleep disturbance are shown in Fig. 12.

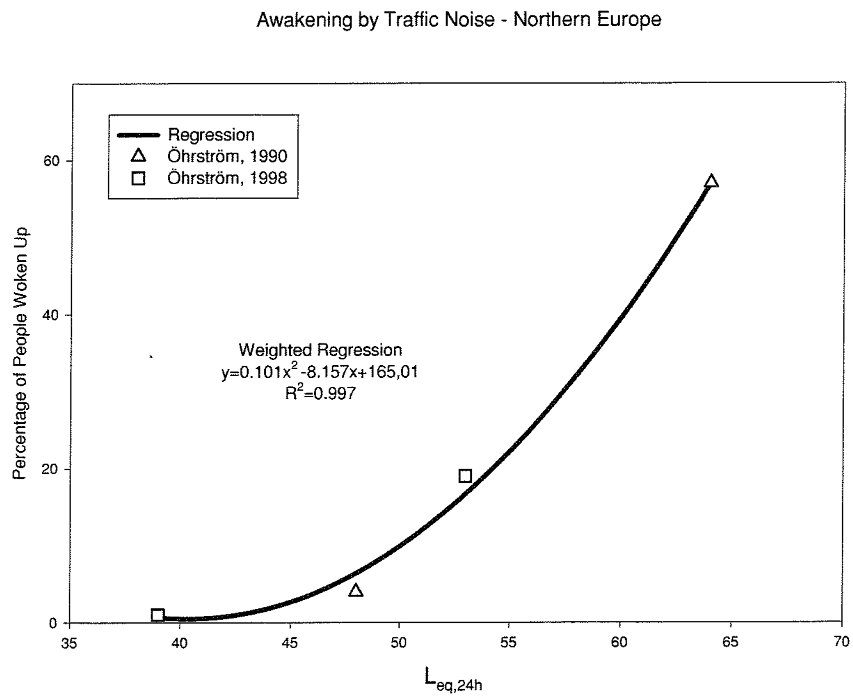


Fig. 12: Percentage of people woken up during the night as a function of energy equivalent continuous sound level. The figure shows the results of two studies in Northern Europe [Öhrström et al., 1990; Öhrström et al., 1998] together with the polynomial fit of the weighted data.

Central Europe

The studies from Central Europe (3, 6) could not be taken into a comparison since the data could not be converted into a dose response curve.

Southern Europe

Study No. 2. **"Road traffic noise and sleep disturbance"** [Garcia, A. u. Romero, J., 1987] 543 residents from three different districts of Gandia were interviewed about different topics such as discontentment with noise, and activities disturbed by noise. 15 questions dealt directly with aspects of the sleep disturbances due to noise. Noise measurements took place over a period of 24 hours outside the front side of the buildings. The calculation of the nightly level was carried out with method 3 (see annex).

Study No. 14. **"Subjective Annoyance Caused by Environmental Noise"** [Aparicio-Ramon, D.V., 1993] 215 persons in Natzaret were surveyed in writing on various subjects (119 questions), among other things noise effected sleep disturbance. The equivalent continuous sound level measured in the study was converted by example parameters into a $L_{eq,24h}$ (Method 1; see annex) and then estimated by the German recommendation RLS 90 to $L_{eq,8h}$ (method 3, see annex).

Study No. 15. **"A Social Survey on the Effects of Environmental Noise on the Residents of Pamplona, Spain"** [Arana,M. u. Garcia,A. 1998] Altogether 496 persons were questioned, among other things, about their individual attitudes towards noise and noise effected sleep disturbances in five parts of Pamplona (sleep disturbance, awakening reactions). The noise level was measured over a period of 24 hours by $L_{eq,24h}$ in an outdoor environment. The night level $L_{eq,8h}$ was assessed with method 3 (see annex).

Study No. 16. **"Community response to environmental noise in Valencia"** [Garcia, A. et al., 1990] The study was carried out in 5 areas of Valencia. 263 interviews were carried out (115 questions). 7 questions referred to the subjective disturbance of sleep. The $L_{eq,24h}$ was measured at various representative places. The night level $L_{eq,8h}$ was calculated with method 3 (see annex).

The results of the interviews were suitable to be summarized in a diagram on nightly awakenings (study 2 and 15). Study 1 could not be included in the comparison since no reasons for waking up at night were indicated (noise induced awakenings did not count).

The data from the Southern countries on sleep disturbance are shown in Fig. 13.

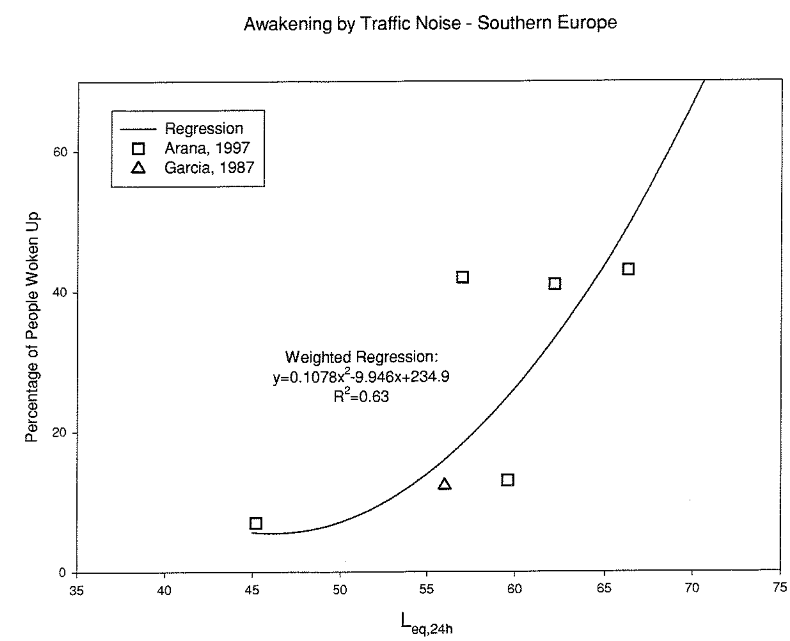


Fig. 13: Percentage of people woken up during the night as a function of energy equivalent continuous sound level. The figure shows the results of two studies in Southern Europe [Garcia et al., 1987; Arana et al., 1998] together with the polynomial fit of the weighted data.

The results of the subjective "awakening reactions" of the studies from North and South Europe were suitable for a comparison. The regression curves of the two European areas are depicted together in Fig. 14.

The curve for Southern Europe falls, after approx. 50 dB (A) $L_{eq,24h}$, clearly under the dose response curve for Northern Europe. Different sound levels for the awakening reaction correspond to the same percentages of persons woken up. The $L_{eq,22-6h}$ of which 15% of the people asked indicated that they were woken up by noise, is approx. 52 dB in Northern Europe and approx. 55.5 dB (A) in Southern Europe. 25% of the people surveyed in Northern Europe indicated that their awakening reaction occurs at a nightly L_{eq} of approx. 56 dB (A), and in South Europe at 59 dB (A). Furthermore 40% of the participants in the studies from Northern Europe claim to have been woken up by traffic noise at 60 dB (A), whereas in Southern Europe the same percentage of people were awoken at L_{eq} 64 dB (A).

Fig. 14 shows the dose-response-curves for Northern and Southern Europe (sleep disturbance / Awakenings by night).

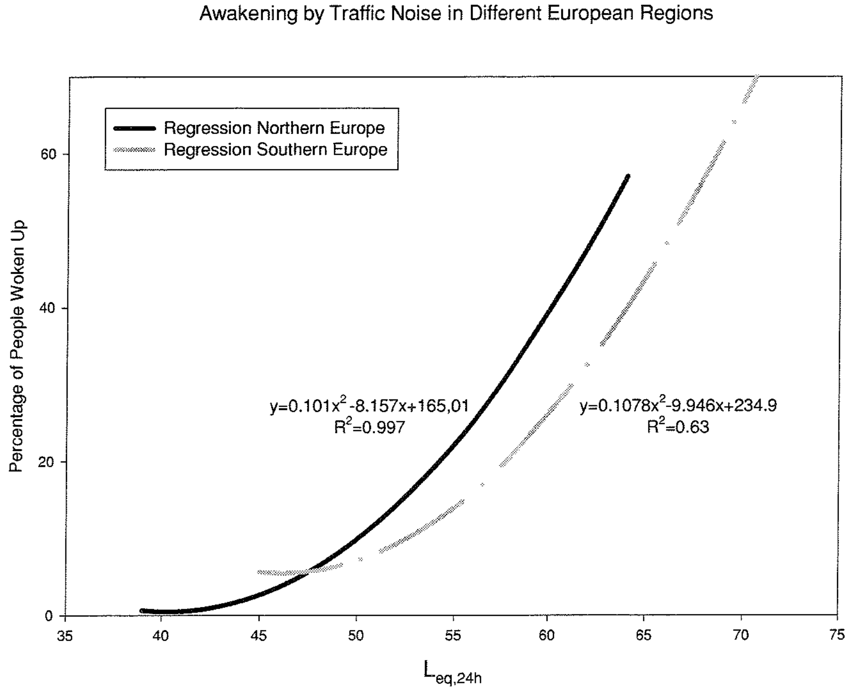


Fig. 14: Comparison of dose response curves of people woken up during the night of Northern, Central and Southern Europe. The lines shown in this figure are identical with the regression lines shown in Fig. 12, Fig. 13 and Fig. 14.

The percentages of awoken persons for Southern Europe lie above the Nordic percentages at below approx. 47 dB (A). However, it should be taken into account that 45.2 dB (A) was the lowest level value represented. The trend line ends here and it cannot be said for sure that the curve maintains the indicated course for lower values. The existing dose-response-curve nevertheless indicates that the people surveyed in Southern Europe do react although less strongly from nightly awakening at higher levels than study participants in Northern Europe . Yet it would seems that more frequent awakening reactions would also be evident at lower levels for Southern Europeans.

Outdoor levels were used in all studies. Again this would coincide with the fact that, in the south, the indoor sound levels might be higher than in the Nordic countries due to the lighter style of buildings in the south, the lack of thicker outer walls and frequent use of double glazing.

Table 14 shows the respective levels and reactions stated for comparison. The laboratory studies weren't taken into account due to intermittent sounds and due to the fact that only inside levels were used.

Table 14: Comparison of some indicators for sleep disturbance, between Northern and Southern Europe

	Nr.	Leq, 8h or 9h in dB(A)	Falling asleep duration	Falling asleep difficulties	Subjective sleep qualitatively	Morning tiredness
Northern Europe	9	54	22 min.	25%	significantly worse	Morning significantly higher
		39	15 min.	2-3%	significantly better	Morning significantly lower
	8	64	44	37%	significantly worse	Morning/daytime significantly higher
		48	25	8%	significantly better	Morning/daytime significantly lower
Southern Europe	1	69,5	not significant	significantly higher (M = 2,03 ± 0,80)	significantly worse (M = 3,40 ± 0,87)	significantly higher (M = 2,85 ± 0,82)
		39,8	not significant	significantly lower (M = 1,85 ± 0,70)	significantly better (M = 3,62 ± 0,81)	significantly lower (M = 2,59 ± 0,83)
	2	52	-	17%	-	-
	14	72,9 and 66,8	-	25%	-	-
		61,1 and 55,8	-	8 %	-	-
		67,9 *	-	27 %	-	-
	16	55	-	25,1 % very much and much	-	-

*: the level was averaged, where work and weekend were put days together. The night levels are fundamentally higher at the weekend so, for a great portion, the sleep disturbance found probably also refers to the weekend nights as well as to weekdays.

Table 14 does not show any essential differences for the subjective sleep quality and the morning and day tiredness. More exact details should have been available for a more specific comparison. It should be pointed out, that with the available data from the studies of both countries, the subjective sleep quality was worse and tiredness was increased significantly by noise. A comparison of the sleep latency (duration of time spent falling asleep) was not possible, since no figures were made in minutes or this parameter was not used.

In Fig. 15, the trend-curves for difficulties in falling asleep for Northern and Southern Europe are shown.

As Fig. 15 indicates, the Southern European residents have less problems falling asleep than the people surveyed in the Nordic countries. The data points from Southern Europe (study Nr. 2) were averaged from 3 different areas with varying noise disturbance. One area had an equivalent continuous noise level of 65 dB (A) at night. It should be noted that there was no reference in the study indicating from which of the different areas the people interviewed came. If it is assumed that the majority of the people reporting problems with falling asleep were form the louder area, the data points compare well with the points from the other Southern European studies. In conclusion there appears to be a greater sensitivity to noise on the part of Northern Europeans, compared with the Southern Europeans who have less difficulty falling asleep by higher noise levels.

It must be stated that conclusions cannot be easily made due to the scarcity of data and the partly missing or inaccurate details. The extent of the aggravations of the sleep quality would have to be described more exactly as well as the tiredness from noise in the morning or during the day. The represented differences of falling asleep, as well as being awoken by noise, between Northern and Southern Europe have to be taken very cautiously as the respective studies for Northern Europe come only from Sweden and for Southern European almost unanimously from Spain.

In general the discrepancies between the different studies suggest that considerable differences regarding sleep disturbance through noise may exist between the different areas in Europe. To prove this assumption further, studies with a standardised and evaluated methodology are necessary. A standardised European interviewing and testing inventory for sleep disorders is urgently required in order to examine the effect of noise on sleep disorders comparable in all parts of Europe.

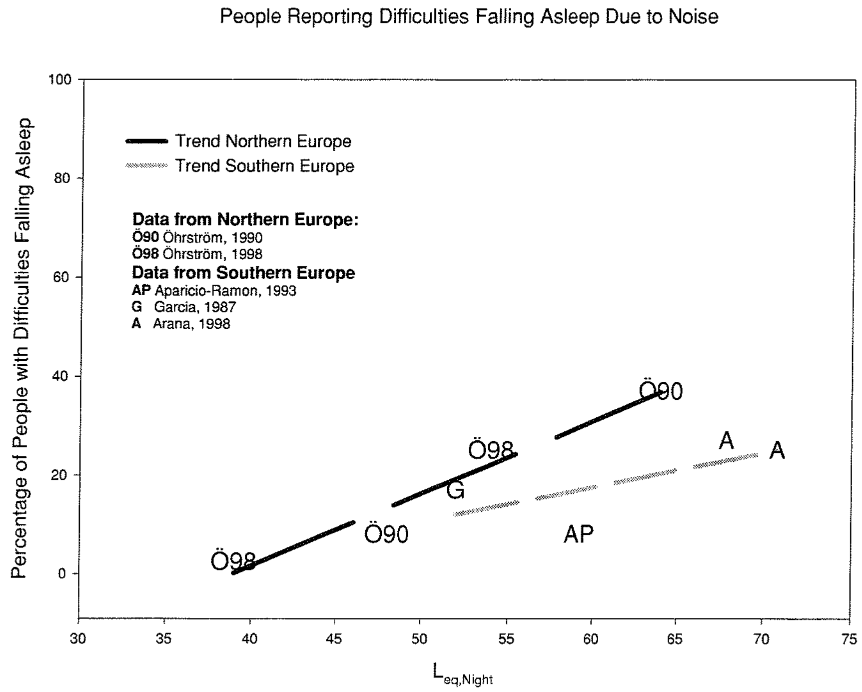


Fig. 15: Percentage of people with falling asleep difficulties as a function of energy equivalent continuous sound level. The figure shows the results of two studies in Northern Europe [Öhrström et al.,1990; Öhrström et al., 1998] together with the results of two studies in Southern Europe [Garcia et al., 1987; Aparicio-Ramon, 1993]

3.3.4 Disturbed activities

Additional matters of scientific and practical interest are the daily activities disturbed by noise and especially the possible existing differences in the various European regions. One could suspect that persons are rather more disturbed by noise generated by indoor domestic activities in Northern Europe because people spend more time indoors in colder regions. In Southern European countries people prefer outdoor activities. Therefore data retrieved from the literature was also searched through for this kind of information. The results are represented as follows.

Northern Europe

In the study at the Oslo airport [Gjestland, 1990], people surveyed were asked whether they felt disturbed with reference to their ability to concentrate. The amount of people who answered "yes", depends on the 16 hour equivalent continuous sound level (see Table 15).

Table 15: Share of persons disturbed by aircraft noise in relation to concentration [Gjestland,1990]

$L_{eq,16h}$ in dB(A)	< 60	> 65
Disturbed persons	Less than 10%	More then 20%

Central Europe

A very detailed study on disturbed activities was published by Felscher Suhr et al. in 1996. The study was carried out in four residential areas in Düsseldorf and Ratingen in 1994.

There was either traffic noise or aircraft noise by an equivalent continuous sound level of approx. 60 or 70 dB(A).

The authors concluded that the aircraft noise increases the recovery need as well as reduces the sleep quality and must be compensated by quantity. They assume that with traffic noise, due to the more uniform structure, these disturbances are not caused to the same extent.

Regarding garden activities, the study indicated that the people in the noisier areas stayed just as frequently in the garden as those in the quieter areas.

In the case of housework there were differences, however, between the high level and the lower level areas, as well during the interactive communication.

The differences between flight and traffic noise were also examined by a Swiss study.

[Oliva u. Hüttenmoser, 2000]. The effect was that aircraft noise disturbs the active and passive communication, but traffic noise had a far greater effect on disturbing rest and recovery as well as falling asleep and continuing sleep at night.

De Jong [de Jong, 1992] determined the percentage of persons disturbed by aircraft noise at different sound loads when reading, see Table 16:

Table 16: Share of persons, [de Jong, 1992], disturbed by aircraft noise when reading

Leq,24 in dB(A)	46-50	56-60	61-65	66-70
Percentage of persons disturbed by aircraft when reading (%)	5	30	30	35

Southern Europe

Garcia and Faus [1993] reported in their study on aircraft noise effects, that many of the activities of the examined persons were disturbed by aircraft noise, for example listening, conversation, reading and sleep.

In an Italian study [Bertoni et al. 1998] the most frequent effects of traffic noise mentioned by people surveyed were disturbing passive communication, the impossibility to have windows open or to sit on balconies as well as annoyance at reading. The authors discovered two threshold values: the beginning of disturbance lie between 58 and 60 dB(A) ($L_{eq,24h}$ from the L_{dn} converted) and the considered intolerable disturbance at 66 to 68 dB(A) ($L_{eq,24h}$).

Conclusion

The activities resulting from the interviews are compared in Table 17.

Table 17: Activities disrupted by noise

Activities	**Northern Europe**	**Central Europe**	**Southern Europe**
Homework		+	
Active comunication		+	+
Pasive comunication		+	++
Reading		+	++
Concentration	+		
Recreation		++	
Sitting on the balcony			+
Garden working		+	

Many of the activities which are mentioned or surveyed in Southern and Central Europe are equal. The assumption that disturbance by noise, effectively through more outdoor activities, in Southern countries is greater could not be confirmed. For Northern Europe there was not enough information. The existing data from Central and Southern Europe were not directly comparable.

In conclusion, it should again be noted that, due to the scarcity and incompatibility of data, clear differences between the various European regions could not be demonstrated nor made improbable.

3.3.5 Window opening behaviour

Among other things the strategy most often used by people disturbed or annoyed by environmental noise is to close the windows. It would seems a reasonable assumption to say that, due to the climatic differences in Europe, this kind of noise avoidance might be very different. Thus, for example it can be assumed that windows are closed less frequently in Southern countries due to the high temperatures even if higher outdoor noise pollution exists. To confirm whether such differences are actually available and how they can affect the noise annoyances or the sleep disturbances caused by noise, literature references were searched through for indications of window opening behaviour.

Northern Europe

In a Swedish study [Öhrström, Agge and Björkman 1998] on sleep disturbance by traffic noise, the participants were asked if they opened their windows at night. For a nocturnal sound level of 54dB(A), 90% of the participants open their windows sometimes, or seldom/never. In the control group (L_{Aeq} = 39 dB(A)) 59% of the participants open their windows sometimes, or seldom/never. For the calculation of the nocturnal L_{eq} please see the chapter on annoyance by aircraft noise.

Central Europe

In one of the publications from Austria [Lercher and Kofler, 1996] it is indicated that a highly significant proportion of the people interviewed kept the windows closed at $L_{eq,24h}$ > 55 dB (A) both at night and during the day.

The authors of a study from Amsterdam [Meijer, Knipschild, Sallé, 1985], presented their results by indicating the number of people who kept their windows closed in relation to how much noise they came into contact with. The noise levels of the most exposed side of the house were used. See Fig. 16.

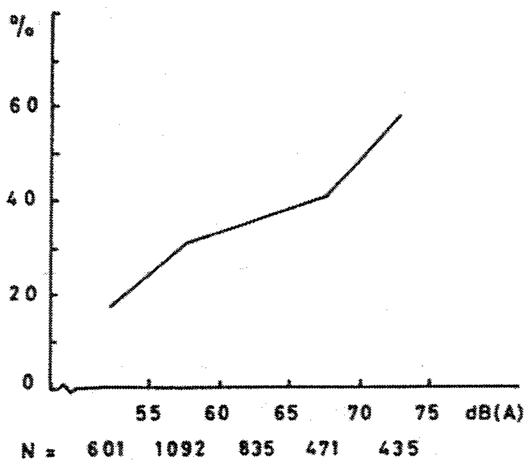


Fig. 16: Percentage of people who closed their windows at noisy sides of the building in Amsterdam (Source: Meijer, Knipschild, Sallé, 1985)

At outdoor sound levels of 55 dB(A), approx. 25% of the affected persons closed their windows, increasing to approx. 34% at 60 dB (A). 38% of the asked people kept their windows closed at 65 dB (A) and 48% by 70 dB (A).

In addition, the authors stated that the bedroom windows were closed at night by 3.2% of the people surveyed on the more quiet side of the building, as opposed to 23.4% of the people whose bedroom was on the noisy side.

[Berglund, Lindvall, Nordin, 1990] reported that in the Netherlands 80-90 % of the population sleep with open windows at night in summer and 60-65%. in winter. The reasons for an aversion to closed windows are: the feeling of a loss of liberty, bedroom smells and too high temperatures. In Great Britain 66% of the residents near to the airports Heathrow and Gatwick also slept with open windows.

Southern Europe

About 25% of the residents in Valencia (Spain), in three areas highly exposed to noise with night levels of 67, 68 and 73 dB(A), slept with closed windows. Only 7% of the people of two quieter areas, with $L_{eq,22\text{-}7h}$ of 56 or 61 dB(A) did this [Garcia et al., 1990].

23% of the people (n=543) surveyed in Gandia (Spain) reported sleeping with windows closed at night [Garcia a. Romero 1987]. 59% of them named traffic noise as the main reason. In total, 14% of people closed their windows at night mainly because of the traffic noise (averaged over three areas for $L_{eq,22\text{-}6h}$ approx. 52 dB (A)). 29% of the persons who lived in a quieter area named traffic noise as the main reason for sleeping with closed windows, in comparison with 85% in the loudest areas with nightly levels of around 65 dB (A).

10% of the people surveyed in Natzaret (Spain) on annoyance by environmental noise [Aparicio-Ramon et al. 1993], reported sleeping with closed windows at night because of the traffic noise. For the calculation of the nocturnal sound level of 55 dB(A) see chapter annoyance by aircraft noise.

The percentage of the people surveyed in Pamplona (Spain) who kept the windows closed at night, is shown in Table 18 below for the five examination areas of the study [Arana and Garcia 1998].

Table 18: [Arana U . Garcia, 1998,], Share of the people asked who slept with their windows closed at night.

	San Jorge	San Juan	C. Viejo	Ensanche	Chantrea
Leq, 8h	67,3	56,2	61,6	59,6	45,4
% of closed windows	75	52	46	32	24

Conclusion

In Fig. 17 the trend-curves for sleeping with closed windows from Northern, Central and Southern Europe are shown

The two data points for Northern Europe, which are clearly different from the others, can be explained, on the one hand, by different kind of questions which were asked in the survey and, on the other hand, by the fact that people in northern countries generally sleep with closed windows, even in the middle of the summer. This data therefore cannot be compared.

Although the data points vary widely for Southern Europe and those for Central Europe seem to be remain fairly stable, increasing with noise levels, there seems to be a trend of closing the windows more frequently with higher noise pollution in Southern Europe. A clear conclusion is impossible to make since the data from Central Europe arose from one single study only and a similar variability as in South Europe is not available. The results from [Lercher and Kofler, 1996] finally indicate, for example, a very high percentage of closed windows already after 55 dB(A).

Particularly with respect to sleep at night, many people kept their windows closed at high noise levels even in Southern countries despite the high temperatures in order to avoid their sleep being disturbed. This represents a higher demand for sleeping with closed window in Southern countries. To keep windows closed at night due to the noise is therefore an indication of a high annoyance for these people [Meijer, Knipschild, Sallé, 1985]. A particularly strong annoyance reaction should therefore be inferred for residents of Southern countries if they close the windows due to outdoor noise.

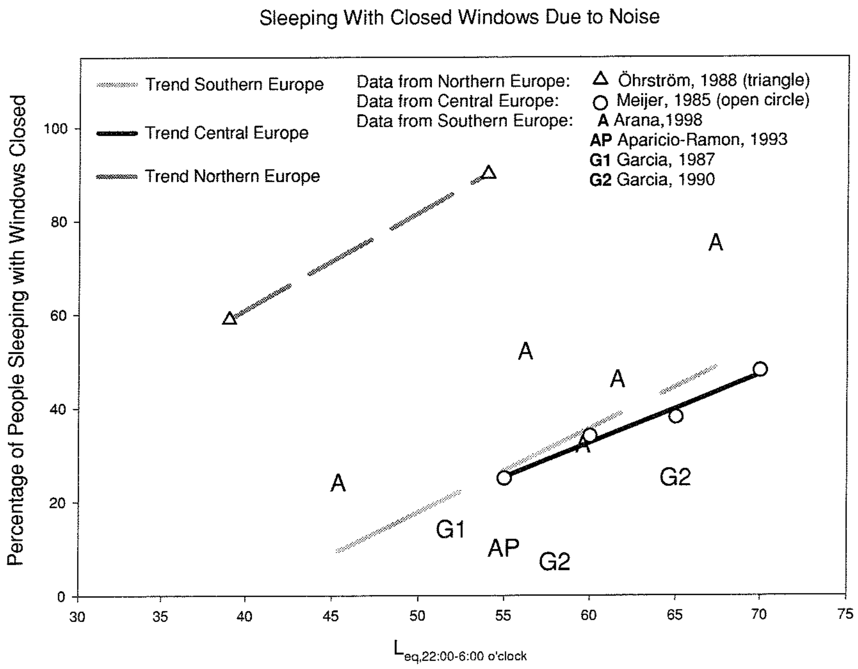


Fig. 17: Percentage of people which slept at night with closed windows as a function of energy equivalent continuous sound level. The figure shows the results of one study in Northern Europe [Öhrström et al., 1998] together with the results of one study in Central Europe [Meijer et al., 1985] as well as the results of four studies in Southern Europe [Garcia et al., 1987; Garcia et al., 1990; Aparicio-Ramon, 1993; Arana et al., 1998]

4 Evaluation of Questionnaires from Europe to traffic noise pollution

In addition to the results of the literature evaluation a small interview for Europe was created on the effects of traffic noise. The questionnaires were sent to experts (scientists, authorities, citizen-initiatives) in Europe. The complete return quota lay was approx. 21.1%, so that the results of the interview were unsafe. For the Nordic countries three questionnaires were returned, for Central Europe 12 and for Southern Europe 18 questionnaires.

Table 19: Return quota of the questionnaires

European Area	Country	Sent	Returns	Percentage
NORTH	Sweden	4	1 + (1)[1]	50
	Denmark	3	1	33.3
	Norway	5	1	20
	Finland	2		
	Iceland	1		
	Estonia	5	(1)[2]	20
	Latvia	9		
	Lithuania	2	(1)[3]	50
		31	**6**	**19.35**

European Area	Country	Sent	Returns	Percentage
CENTRAL	U.K.	6	1	16,6
	Germany	5	5	100
	Netherlands	4	2	50
	France	6	1	16.6
	Austria	3	1	33.3
	Switzerland	3	2	66.6
	Ireland	3		
	Belgium	4		
	Luxembourg	4		
		38	**12**	**31.6**

European Area	Country	Sent	Returns	Percentage
SOUTH	Spain	33	13	42.4
	France	22	2	9.1
	Italy	15	1	6.7
	Portugal	8	1	12.5
	Greece	9	1	11.5
		87	**18**	**20.7**
	TOTAL	**156**	**36**	**23.1**
	Return quota:			**23.1%**

1 The interviews from the Baltic states were not included in the calculation since here a politician and a navy expert have answered but not noise researcher.

2 The results of the interview with an expert of the Swedish town Kiruna suggested that the noise load in the mining town is not comparable to other regions (shift work, mining traffic). The results for Kiruna are given in Fig. 18

3 (See footnote 2)

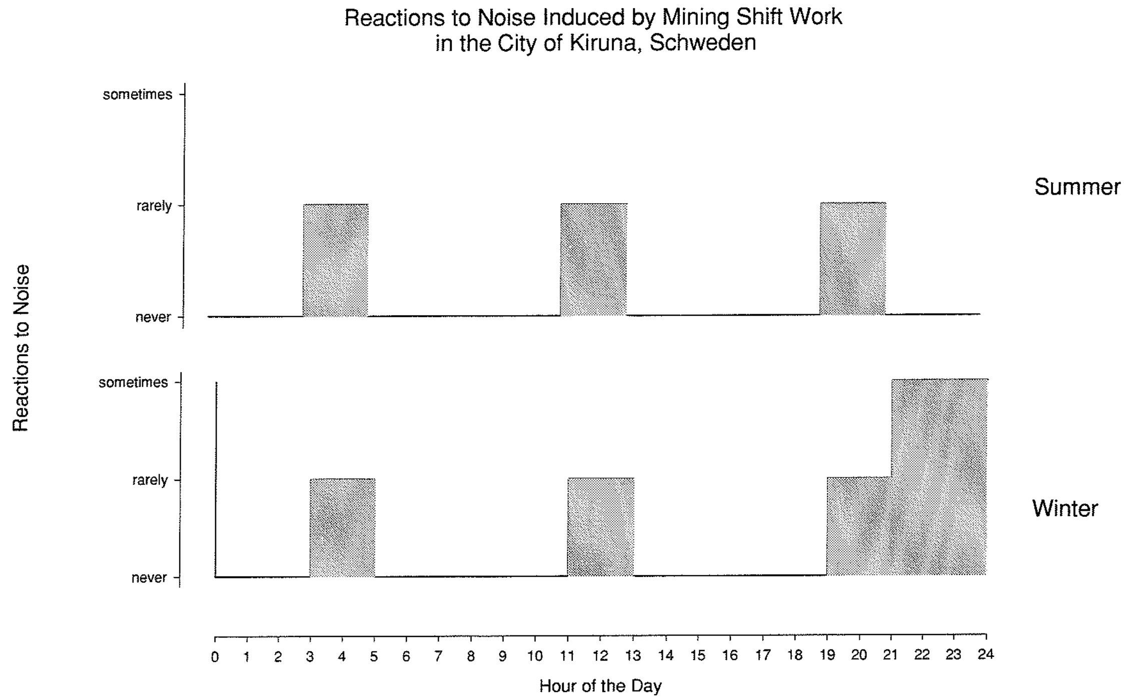


Fig. 18: Differences of noise induced reactions in the far Nordic city of Kiruna between summer and winter (answered by an expert from Kiruna, Sweden; possible sleep time in summer 8h and in winter 12h)

4.1 Main work focus and position of experts

Table 20: Expert position

		European Area		
		north	central	south
		N° in percent	N° in percent	N° in percent
Expert position	researcher or teacher	3.8%	19.2%	26.9%
	engineer	3.8%	3.8%	3.8%
	public health department		11.5%	7.7%
	citizen initiatives		11.5%	7.7%

Table 21: The main work focuses of the experts

	European Area		
	north	central	south
Health care	1	10	8
Technical acoustic	2	3	4
Administration	1	2	5

4.2 Noise induced sleep disturbance

The topics sleep or sleep disturbance and annoyance have already resulted in a greater number of statements from the experts than expected. Knowledge about vegetative-hormonal reactions (triggered by noise) was previously little known by the experts.

Table 22: The possible sleep time during the day (in hours)

		European Area		
		north	central	south
Possible sleeping time	7 h	1		
	8 h	1	5	5
	9 h	1	5	5
	10 h		1	3
	11 h			1
	12 h		1	
	13 h			1
	15 h			1

In Fig. 19 the duration of sleep (in hours) according to the experts does not differ significantly throughout all three parts of Europe (north, central, south).

A significant difference consists in the sleep pattern at the actual time people slept. This connection is clarified in Fig. 19.

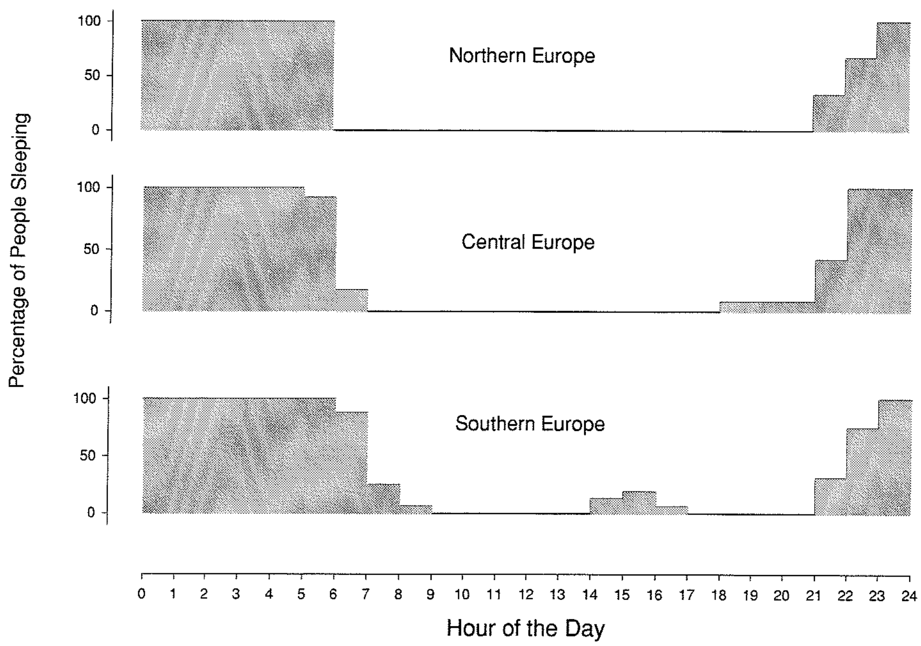


Fig. 19: Different sleep course in North Central and South Europe

The mean sleep duration is not statistically different, but Fig. 19 shows that people from Northern and Central Europe wake up earlier than people in Southern Europe. The greatest difference between the European regions is the daytime sleep in Southern Europe – although only a few people had an afternoon nap (ca. 25%). No differences exist between the mean sleep course of Northern and Central Europe.

The mean sleep course in Southern Europe is significantly different to the sleep course of Northern and Central Europe.

The differences in the sleep course may be important for guidelines within the EU. The answers of the experts suggested that specific restrictions on evening hours cannot generally be established in Europe. It is not surprising that Spain required a later period of time for noise prevention in the evening hours. whereas Finland was supporting an earlier period of time (EU 2001).

For Europe significant differences in sleep disturbance were given through information from the experts.

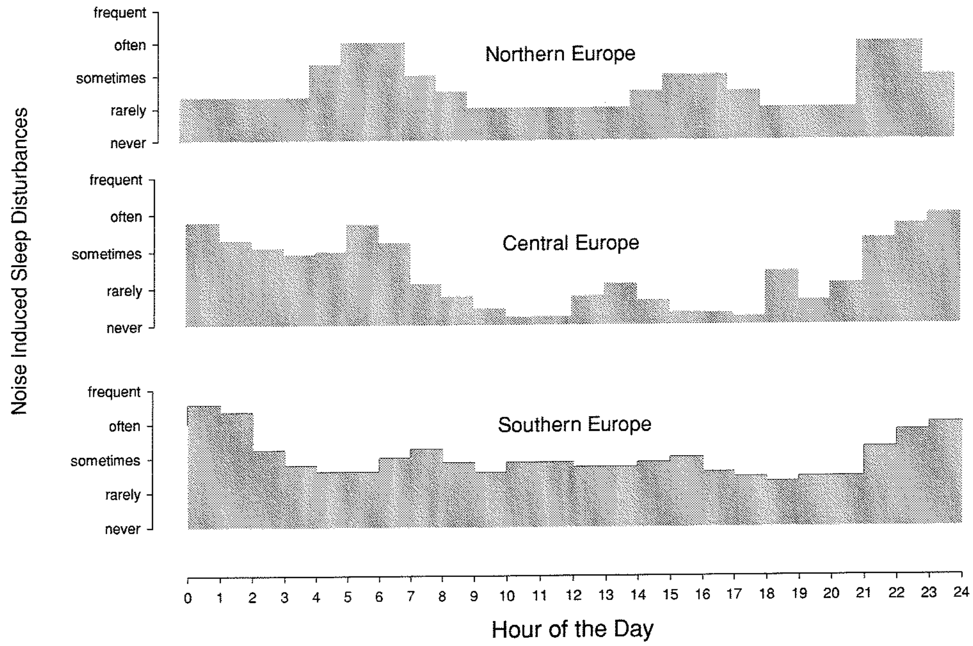


Fig. 20: Time of sleep disturbances over 24 hours

The answers to the question "at which time do sleep disturbances mostly appear?" was significantly different between the regions of Europe. The daytime from 7-22 hours was not significantly different. The statistical differences only exist within the night time hours (23-6 h). (see Fig. 20)

Additionally, there are differences about the causes of sleep disturbance shown in Table 23.

Table 23: Causes of sleep disturbance (cont.)

	European region		
	north	central	south
road traffic noise	3	10	15
railway noise	1	7	3
flight noise	1	10	7
municipal service noise	1		7
leisure noise			10

Road traffic noise was mentioned as the dominant noise source. In Central Europe flight and railway noise must be taken into account. In Southern Europe the experts highlight additional municipal services noise e.g. waste collection vehicles, commercial refrigerators, ambulance sirens, ventilators and leisure noise e.g. bars, parties, parks, discotheque, music cafes, social and tourist activities.

4.3 Vegetative-hormonal reaction

The questions on knowledge for noise induced vegetative hormonal disturbances were only answered by individual experts.

An evaluation of the descriptive statistics does not lead to any interesting results.

4.4 Annoyance

The responses for the question as to where the annoyances most frequently appear is shown in Table 24.

Table 24: Where annoyance occurs: inside / outside / both (percentage)

Annoyance	European region		
	north number in percent	central number in percent	south number in percent
outside	3.6%	10.7%	3.6%
inside	7.1%	17.9%	32.1%
both		14.3%	10.7%

In Northern Europe annoyance is mostly associated with inside noise, as expected. In the Southern Europe annoyance mostly appears inside too – that unexpected information may be the result of lower sound insulation.

5 Dissemination

5.1 The internet homepage

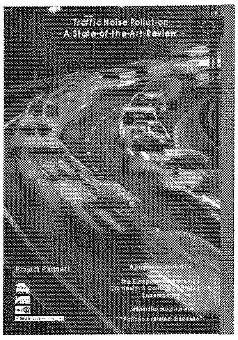
The Traffic Noise Pollution – A State-of-the-Art Review 2000 – 2001 - web site can be found at the following internet address:

www.tu-berlin.de/bzph/tnp2001

5.2 The maxi brochure

A maxi-brochure has been produced and is available by writing to the following address:

bzph@tu-berlin.de



6 Summary

It is well known that the interference of noise in everyday activities (annoyance) correlates with the exposition level. A threshold of 55 dBA exists for activities which demand attention and concentration and 65 dBA for activities that imply the word perception. Communication interferences therefore appeared when noise levels went 10 dBA over voice emission levels (50 to 60 dBA). 65 dBA of environmental noise seriously affects speech intelligibility, with a very important impact on education tasks. The importance of the main effects of high noise levels on aggressiveness, must also be mentioned as they expose those who are particularly predisposed or inclined to these effects.

Sleep disturbance has been the object of many researches due to it being one of the noise exposure consequences, particularly from traffic noise. There are two types of effects, firstly primary, which occur in the moment of the exposure and consist of insomnia, difficulty in getting to sleep and waking up twice or three times during the night. The secondary effects happen the next day and consist of change of mood, tiredness, and with a diminish of physical and mental performance.

Noise is a relatively small academic study theme in the majority of countries around the Baltic Sea. This is no doubt due to the minimal noise problems in the area. On the contrary, Sweden carries out some high level noise research and to some extent coordinates the Nordic noise research and development.

There is a difference in sleep disturbances between summer and winter in northern Scandinavia, which can be explained by the very different daylight and climate conditions in the very north of the region. The population has different sleeping patterns depending on the amount of daylight linked with specific industrial activities.

75% of all noise-induced sleep disturbance is related to road traffic. 23 % is related to rail and air traffic and 2 % to other traffic noise sources.. However, the level of insulation in walls and roofs has the same positive impact on the climatic conditions in Scandanavia as those regarding traffic noise.

Furthermore, the behaviour of window opening for climate reasons as well as specific building techniques are also different to Southern country noise prevention. More than 90% of Swedish, Finnish and Norwegian homes have 3 or 4 glass windows. This means that the interiors are protected against cold and also against noise.

Most people in the region do not sleep with open windows because it gets too cold even in the middle of the summer, (below 20 degrees). Noise pollution is a problem in larger towns in highly populated rural areas. The low density populations offers a wide availability of free space whereas roads, airports, harbours and railways are built away from densely populated areas. This low density population ensures that recreation areas, etc., are always at a distance from noise sources, such as roads and airports.

This tells us that a higher sensitivity to noise pollution exists in Northern Europe compared with Southern Europe. The main factor being the overall lack of noise exposure. This can be explained by two factors, the first being low density population, which creates free space to live in, the second being that urban planning has focused on the separation of living and industrial areas leading to an overall lack of noise pollution. Northern Europeans are "spoiled with silence".

Most of the noise research studies were carried out in Central Europe, but the results did not give a clear picture. Dose response curves from Central Europe are sometimes similar to dose response curves from Northern Europe (annoyance by flight noise) as well as to dose response curves from Southern Europe (windows opening behaviour). The annoyance reactions to traffic noise (street noise, flight noise) in Northern and Southern Europe are much more clearer than the reactions from Central Europe. The dose response curves from Central Europe are based generally on far more scattered values (always a small R^2 at traffic noise and at flight noise).

It seems reasonable to explain that these great differences occur partly due to the climatic conditions, which are not so homogenous for Central Europe as for Northern or Southern Europe (e.g. The North of France in relation to the South of France). On the other hand, there must be other strong influences to explain the great differences within the studies, such as differences in cultural attitudes.

The majority of the grey literature reviewed in the South of Europe shows a clear tendency: it focuses mainly on noise subjective reaction, annoyances as well as sleep disturbances. In general, the daytime hours in which people in the South of Europe sleep is between 23 and 7 hours, apart from Spain which includes a short nap between 15 and 16 hours.

Laboratory studies to measure physiological noise reaction in the human organism are rare, even when noise is considered a factor that contributes to environmental stress reaction, that can possibly produce negative health consequences. Vegetative and hormonal reactions are, at the moment, one of the least developed fields of research in the Southern European region (only three research teams have been found working on this issue). Psychological and physiological reactions to noise were emphasized in the rest of the studies. Most of them focus on annoyances, such as communication interference, cognitive development damage in children, sleep disturbances, etc

The experts consulted around Southern Europe were not able to answer the questionnaire completely. Only one Spanish expert delivered an almost complete document (95%). 84 % of experts knew the existence of noise map data in their countries. 11% answered negatively to this question (mostly from Spain & Portugal). The rest did not answer.

Most of the experts are aware of noise induced sleep disturbances in their countries. They report that sleep disturbances usually occur during the night between 11p.m. and 8a.m. However, these disturbances also occur during the day. 50% of the experts knew some of the noise related human health effects and they quoted some of them, such as neuroendocrines disturbances, increase in blood pressure and heart rate and respiratory frequency enhances. Only two of them answered affirmatively (11%) to this part of the questionnaire. 89.5% of the experts were aware of noise induced annoyances. Most of them considered that annoyances occur more frequently inside (52.6%), 16.6% outside and 16.6% in both places.

The main causes of noise effects, according to the Southern European experts are, in order of frequency: urban traffic (88%), bars (35%), pubs (35%), discos (35%), airports (35%), leisure noises (29%), garbage collection(29%), industries (12%), public works (12%), ambulance sirens (12%), people noises (6%), domestic animals (6%), people's voices (6%), highways (6%), freight train lines (6%) and train stations (6%).

7 Conclusions

International literature

To evaluate the differences of noise effects in Europe, a literature inquiry was carried out. Only primary studies were taken into account which could provide a sufficient comparison. A lower annoyance reaction from people surveyed in Southern Europe in comparison to Northern and Central European people is first main outcome of the study. It should be noted that data from Northern Europe comes from two countries (Norway and Sweden) while the South European data was collected only in Spain. The source of the Central European data was collected from three countries (Germany, the Netherlands and Switzerland), therefore conclusions may not be entirely representative. With the results available it can be shown, however, that differences regarding the annoyance reaction by traffic noise certainly exist between the individual countries. The division of Europe into Northern, Central and Southern regions was a key issue of the project and had an important impact on the results. The findings of the literature inquiry suggest that there are differences between Northern and Southern Europe. Central Europe, however, does not look like an independent homogenous region. Dose response curves from Central Europe are sometimes similar to dose response curves from Northern Europe (annoyance by flight noise) as well as to dose response curves from Southern Europe (windows opening behaviour). The annoyance reactions to traffic noise (street noise, flight noise) in Northern and Southern Europe are much more clearer than the reactions from Central Europe.

The third main result of the study is the cognition that a difference in noise induced sleep disturbances exists in Europe. The results reveals a greater sensitivity to noise on the part of Northern Europeans, compared with the Southern Europeans who have, for example, less difficulty falling asleep at higher noise levels. It must be stated that the comparison of sleep parameters cannot be easily made due to the scarcity of relevant data and the partly missing or inaccurate details in publication.

With particular respect to sleep at night, many people keep their windows closed at high noise levels, even in noise polluted cities in Southern countries, despite the high temperatures, to avoid a disturbance to their sleep. This represents a high demand, to sleep with closed windows in Southern countries. The keeping of windows closed at night due to noise is therefore an indication of high annoyance for these people.

Experts Inquiry

In addition to the results of the literature evaluation, a short interview for European specialists was created to further understand the effects of traffic noise. The questionnaires were sent to experts (scientists, authorities, citizen-initiatives) in Europe. On the whole, the answers of the experts surveyed support the conclusions of the literature evaluation. Knowledge on noise-induced physiological reaction was, like the results of the literature inquiry, also poor in Europe. Furthermore, the duration of sleep given in the inquiry is not significantly different for the different regions of Europe (north, central, south). However, a significant difference is evident in the sleep course, at what times people sleep. The mean sleep course in Southern Europe is significantly different to the sleep course of Northern and Central Europe. The greatest difference between the European regions occur due to the traditional daytime sleeping patterns in Southern Europe (although only approx. 25%.people took a siesta) and the varying daylight hours in Northern Europe.

Common Aspects

The international literature as well as the experts inquiry underline the increasingly growing importance of the traffic noise problem in the area of public health. In the future a standardised European interviewing and testing inventory for noise effects is urgently needed in order to get comparable results from all parts of Europe.

The interference in the activities increases with the outside exposure level. A threshold of 55 dB(A) may exist for outside activities which demand attention and concentration and 60 dB(A) for activities that imply the word perception. Communication interferences therefore appeared when voice immision levels are 10 dB(A) less than noise levels. The importance of the main effects of high noise levels on aggressiveness, must also be mentioned as they expose those who are particularly predisposed or inclined to these effects.

Sleep disturbance has been the object of many researches due to it being one of the noise exposure consequences, particularly from traffic noise. There are two types of effects, firstly primary, which occur in the moment of the exposure and consist of insomnia, difficulty in getting to sleep, disturbing the sleep structure and waking up during the night. The secondary effects happen the next day and consist of change of mood, tiredness, and with a diminish of physical and mental performance. Studies with a standardised and evaluated method are necessary to prove the differences between European regions. A standardised European interviewing and testing inventory e.g. for sleep disorders, is urgently needed in order to examine the effect of noise on sleep disorders comparable in all parts of Europe.

Annexes

Annex 1. The questionnaire

Personal Introduction to the QUESTIONNAIRE

Dear Noise Expert,

A European noise project is underway entitled: **Traffic noise Pollution and Health 2000: A state-of-the-Art-Review**. This project is financed by the European Commission and will gather and evaluate traffic noise data from all European Member States. In order to get a full overview from the different European countries, we would kindly like to ask you, as a qualified noise expert for your country, to fill in the following questionnaire about traffic-noise and related health effects. We would greatly appreciate it if you would take this time for this European project.

We would like to publish all expert's names in the final report, (however not in direct context with your answers).

Questionnaire

Classification:

In order to classify your answers, please give us some information about your position.

What are your main work focuses / fields of operation?:

For which geographical region will you give the answers?:

Please explain briefly, what your link is to noise, including related health effects:

Please answer all questions:

<u>Noise maps</u>

Is there any data for usual noise pollution (noise maps) available for your region/ your country?

YES ☐ NO ☐.

Are you familiar with acoustical sound levels?

YES ☐ LITTLE ☐ NO ☐.

Sleep

Sleep distribution:

1. In general, at which times of the day do people sleep in your country/region?

Please specify the longest season in your country:

hour	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5

Please mark the time-periods on the above time-scale with bars or crosses.

2. Are you aware of noise-induced sleep disturbance in your region/country?

YES ☐.

NO ☐.

3. If YES, at which times do sleep disturbances most often occur and how often do they occur at these times?

(Please use a scale from never to frequent, for the stated times of day on the pre-determined time-rail by using crosses)

(like this example)

Fre-quence																					x			
Often																		x	x	x		x	x	
Sometimes	x								x							x	x							x
rarely		x		X	x		x	x		x	x	X			x									
Never			x			x							x	X										
Hour	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5

(Please fill in here)

Fre-quent																								
Often																								
Somet imes																								
rarely																								
Never																								
Hour	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5

4. **Which sound-sources are the main cause of the above mentioned sleep disturbances in your region/country?** (for example: urban traffic, highways, railways, civilian or military airports.)

Sources:

5. **Please state to what intensity noise sources must reach, to be associated with an increased level of sleep disturbance?**

Please fill in the relevant sound-level (Leq) and/or the maximum sound-level (Lmax) or the sound exposure Level (SEL). (From 45 dB(A) in steps of 5 dB)

Source	Leq	Lmax	SEL

6. **Which kind of windows exist predominantly in your region/country?**

(specify: few/some/many/all) ?

	few	some	many	all
single glazing	☐	☐	☐	☐.
double glazing	☐	☐	☐	☐.
treble glazing	☐	☐	☐	☐.
glass with vacuum	☐	☐	☐	☐.
simple-glass	☐	☐	☐	☐.

7. **Please list (up to) 10 of the most important literature sources (reports, pamphlets, grey literature) handling regional/local noise-induced sleep disturbance. If possible please enclose sources, references and/or copies of this literature.**

Vegetative-hormonal reactions

8. Are you familiar with pathophysiological (vegetative-hormonal) reactions in your region/country? (e.g. irregular blood pressure, heart frequency, skin-conductance, stress hormones)

YES ☐ No ☐.

9. If YES, please name the reactions, e.g. irregular heart frequency, skin-conductance, stress hormones. Have you noticed any noise-induced changes?

Please specify your experiences.

Reaction	Noise-induced changes YES	Noise induced changes NO

(Please mark YES or NO with crosses)

10. Are you aware of the times of the day in which the reactions appear especially distinctive?

(Please use a scale from never to frequent, for each stated time of the day in the graph below)
Use crosses to show your results.

(Please fill in here)

Fre- quent																								
Often																								
Somet imes																								
rarely																								
Never																								
Hour	6	7	8	9	1 0	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9	2 0	2 1	2 2	2 3	2 4	1	2	3	4	5

11. Please state to what intensity noise sources must reach, to be associated with an increased level of vegetative-hormonal reaction?

Please fill in the relevant sound-level (Leq) and/or the maximum sound-level (Lmax) or the sound exposure Level (SEL). (From 45 dB(A) in steps of 5 dB)

Source	Leq	Lmax	SEL

12. Do you have any knowledge about possible noise-induced health effects in your region/country?

YES ☐ NO ☐.

13. If YES, please name the noise-induced health effects:

14. Please list (up to) 10 of the most important literature sources handling regional/local noise-induced vegetative-hormonal reactions / health effects:

Annoyance

15. Are you aware of noise-induced annoyance in your region/country?

YES ☐ NO ☐.

16. If YES, please name the predominant causes of this annoyance in your region/country.

e.g. disturbed communication (radio/TV)
disturbed recreation
disturbed mental activities (reading, concentration)

causes:

17. Do these annoyances occur more frequently inside or outside the house?

18.

Inside ☐ Outside ☐.

19. Are you aware of the times of the day in which the annoyance appears most frequently?

(Please use the scale from never to frequent, for the stated times of day on the pre-determined time-rail by using crosses)

Please fill in here)

Frequent																								
Often																								
Sometimes																								
rarely																								
Never																								
hour	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5

20. Please state to what intensity noise sources must reach, to be associated with an increased level of annoyance?

Please fill in the relevant sound-level (Leq) and/or the maximum sound-level (Lmax) or the sound exposure Level (SEL). (From 45 dB(A) in steps of 5 dB)

Source	Leq	Lmax	SEL

21. Please list (up to) 10 of the most important literature sources handling regional/local noise-induced annoyance:

22. Do you have some other comments or information concerning these topics?

Thank you very much for filling in this questionnaire.

Annex 2. International Literature

Annex 2.1 Epidemiological data on traffic noise pollution in Southern Europe

Annoyance

AUTHOR	TITLE	YEAR	COUNTRY
Jonsson E; Kailand et al.	Annoyance reaction to traffic noise in Italy and Sweden	1969	I/S
Garcia A; Miralles JL et al.	Community response to environmental noise in Valencia	1990	E
Aparicio-Ramon DV et al.	Subjective annoyance caused by environmental noise	1993	E
Garcia A.; Faus, L.J.; Garcia A.M.	The community response to aircraft noise around six Spanish airports	1993	E
Arana M.; Garcia A.	A social survey on the effects of environmental noise on the residents of Pamplona, Spain	1998	E
Bertoni	Reactions of people to traffic noise in Modena, Italy	1993	I
Dora C	A different route to health	1999	I
Garai M; Guidorzi P	European methodology for testing the airborne sound insulation	2000	I

Sleep

AUTHOR	TITLE	YEAR	COUNTRY
Garcia A.; Romero J	Road traffic noise and sleep disturbance	1987	E
Garcia A; Miralles JL et al.	Community response to environmental noise in Valencia	1990	E

Vegetative-hormonal reaction

AUTHOR	TITLE	YEAR	COUNTRY
Tomei F; Ruffino MG; Tamao E et al.	Acute experimental exposure to noise and hormonal modifications	2000	I

Annex 2.2 Epidemiological data on traffic noise pollution in Central Europe

Annoyance

AUTHOR	TITLE	YEAR	COUNTRY
Meijer; Knipschild; Sallé	Road traffic noise annoyance in Amsterdam	1985	NL
Jonckheere RE	Evaluation of noise exposure and annoyance around Brussels airport	1989	B
De Jong RG	Community response to noise : A review of recent developments	1990	NL
Schick A	Lärmforschung aus der Sicht der Psychologie	1991	D
Schümer R; Schümer-Kohrs A	Comparison of the annoyance due to railway noise and due to noise from other sources – A review of literature	1991	D
Ising H; Rebentisch E	Gesundheitsgefahren für Gehör und Herz durch laute Musik und Lärm	1992	D
Muller-Andritzky M et al.	Cross-cultural study of annoyance by neighbourhood noise	1992	D
Stansfeld SA	Noise, noise sensitivity and psychiatric disorder: epidemiological and psycho-physiological studies	1992	UK

Babisch W ; Ising H	Traffic noise – exposure, annoyance, health risk	1993	D
Conzelmann-AuerC et al.	Perception of traffic noise in comparison to actually measured noise	1993	CH
De Jong RG	Review : extra-aural health effects of aircraft noise	1993	NL
Miedema, HME	Response functions for environmental noise in residential areas	1993	NL
Schick A	Goals for noise prevention from the standpoint of research on noise effects	1993	D
	Umfrageergebnisse zur Lärmbelästigung in der Bundesrepublik Deutschland	1993	D
McCrae IS; Williams ID	Road traffic pollution and public nuisance	1994	UK
Vallet M	Cross-cultural differences in annoyance response to traffic noise	1994	F
Evans GW; Hygge S; Bullinger M	Chronic noise and physiological stress	1995	D/USA
Kalveram KT	Psychological test theory and the correlation between physical noise level and annoyance	1995	D
Maschke C et al.	Perception and effects of sound. Foundations and state of knowledge	1995	D
Felscher-Suhr U; Guski R; Hunecke M; Kastka J; Paulsen R; Schürmer R; Vogt	A methodological study concerning the actual registration of everyday activities and their disturbances due to aircraft and road traffic noise	1996	D
Jansen G; Schwarze S; Notbohm G	Noise induced hazards to health with special respect to the physiological noise-sensitivity	1996	D
Kastka J et al.	Untersuchung zum Lärmkontingenzkonzept : Akzeptanz, Belästigungsverhalten und Meinungsbild am Beispiel des Düsseldorfer Flughafens	1996	D
Lercher P	Behavioural and health responses associated with road traffic noise exposure	1996	A
Lercher P	Environmental noise and health: An integrated research perspective	1996	A
Ortscheid J	Data on noise pollution. Results of representative population surveys	1996	D
Walker	Environmental – A new key for Health of the Nation?	1996	UK
Bullinger M; Bahner U	Erlebte Umwelt und subjektive Gesundheit	1997	D
Möhler U; Schümer R	Conclusions to the sentential safety of the rail bonus	1997	D
Nitsch W et al.	Geräuscheinwirkungen in Stadtvierteln – eine sozio- und psychoakustische Feld- und Laborstudie	1997	D
Notbohm G	The Oldenburg Symposium on Psychological Acoustics	1997	D
Popp C	Bewertung von Lärmminderungspotentialen mit Hilfe von Betroffenenanalysen	1997	D
Zimmer K; Ellermeier W	A German vision of Weinstein´s noise sensitivity scale	1997	D
Passchier-Vermeer W; Passchier WF	Environmental noise exposure 2	1998	NL
Pruppers MJM; Janssen MPM et al.	Accumulation of environmental risks to human health: geographical differences in the Netherlands	1998	NL
Svejdarova H; Bencko V	Comparison of environmental quality in the districts of the	1998	CZ

	Czech Republic		
De Hollander AEM et al.	An aggregate public health indicator to represent the impact of multiple environmental exposures	1999	NL
Guski R; Felscher-Suhr U; Schuemer R	The concept of noise annoyance: How international experts see it.	1999	D
Hoeger R	Theoretical approaches and results of the psychologically oriented noise research	1999	D
Raglan E ; Sulkowski W ; Prasher D	A comparison of noise induced disability assessments in the UK and Poland	1999	UK
Schick A	Interdiszinarity in acoustics and noise research	1999	D
Zimmer K; Ellermeier W	Psychometric properties of four measures of noise sensitivity: A comparison	1999	D
Babisch W	Health effects of environmental noise – A status report	2000	D
Felscher-Suhr U; Guski R; Schuemer R	International standardisation efforts for the evaluation of noise	2000	D
Griefahn B	Noise effects not only the ears. But can damage to health be objectively evaluated?	2000	D
Guski R	Should medical research on noise effects be withdrawn?	2000	D
Jansen G	Umwelt und Gesundheit	2000	D
Meyer-Baron M	Individuelle Bewältigungsversuche als Vermittler zwischen Verkehrslärm und seinen Wirkungen?	2000	D
Möhler U; Liepert M; Schümer R et al.	The relative annoyance caused by rail road traffic noise	2000	D
Oliva C; Huttenmoser C	Die Abhängigkeit der Schallbewertung vom Geräuschkontext	2000	CH
Parson KC	Environmental ergonomics: a review of principles, methods and models	2000	UK
Passchier-Vermeer W; Passchier WF	Noise exposure and public health	2000	NL
Schuemer R; Schreckenberg D	The effect of stepwise change of noise exposure on annoyance	2000	D

Sleep

AUTHOR	TITLE	YEAR	COUNTRY
Ettema JH	Slaap en nachtelijk vliegverkeer	1991	NL
Griefahn B	Verkehrslärm – psychosoziale und vegetative Wirkungen, Schlafstörungen	1991	D
Griefahn B	Environmental noise and sleep. Review-Need for further research	1991	D
Lipert JP et al.	Relative and combined effects of heat and noise exposure on sleep in humans	1991	F
Fell J et al.	Deterministic chaos and the first positive Lyapunov exponent : a non-linear analysis of the human electroencephalogram during sleep	1993	D
Tassi P; Muzet A et al.	Interaction of the alerting effects of noise with partial sleep deprivation and circadian rhythmicity of vigilance	1993	F
Vallet M; Vallet I	Night aircraft noise index and sleep research results	1993	F
Alders JGM; Maij-Weggen JRH	Regulation of the liming value for aircraft noise at night in the Netherlands – an expert´s proposal	1995	NL

Jansen G; Linnemeier A; Nitzsche M	Methodenkritische Überlegungen und Empfehlungen zur Bewertung von Nachtfluglärm	1995	D
Belojevic G et al.	Subjective reactions to traffic noise with regard to some personality traits	1997	YU
Hecht K; Maschke C	Gesundheitliche Auswirkungen des Verkehrslärm – Nächtlicher Dauerstress	1997	D
Liepert M et al.	Akustische Erhebungen im Rahmen einer interdisziplinären Feldstudie über Schlafstörungen an Schienen und Strassenverkehrswegen	1997	D
Möhler U; Schümer R	Conclusions to the sentential safety of the rail bonus	1997	D
Passchier-Vermeer W; Passchier WF	Environmental noise exposure 2	1998	NL
Jansen G; Notbohm G; Schwarze S	Gesundheitsbegriff und Lärmwirkungen	1999	D
Basner M; Samel A; et al.	Effects of air traffic on sleep – a new research approach	2000	D
Fell J; Mann K et al.	Non-linear analysis of continuous ECG during sleep. I. Reconstruction	2000	D
Meyer-Baron M	Individuelle Bewältigungsversuche als Vermittler zwischen Verkehrslärm und seinen Wirkungen?	2000	D
Passchier-Vermeer W; Passchier WF	Noise exposure and public health	2000	NL

Vegetative-hormonal reactions

AUTHOR	TITLE	YEAR	COUNTRY
Dijk FJH van	Epidemiological research on non-auditory effects of occupational noise exposure	1990	NL
Di Nisi J; Muzet A et al.	Comparison of cardiovascular responses to noise during waking and sleeping in humans	1990	F
Fruhstorfer B et al.	Daytime noise load – a 24 – hour problem	1990	D
Marth E	Noise: Effect on various endocrine and biochemical reactions	1990	A
Pulles MPJ et al.	Adverse effects of environmental noise on health : An interdisciplinary approach	1990	NL
Parrot J et al.	Cardiovascular effects of impulse noise, road traffic noise, and intermittent pink noise at Laeq = 75 dB, as a function of sex, age, and level of anxiety I	1992	F
Petiot JC et al.	Cardiovascular effects of impulse noise, road traffic noise, and intermittent pink noise at Laeq = 75 dB, as a function of sex, age, and level of anxiety II	1992	F
Babisch et al.	Traffic noise and cardiovascular risk: the Speedwell study, first phase	1993	D
Babisch et al.	Traffic noise and cardiovascular risk: The Caerphilly and Speedwell studies, second phase.	1993	D
Babisch W ; Ising H	Traffic noise – exposure, annoyance, health risk	1993	D
Griefahn B; Bröde P; Schwarzenau P	The equivalent sound pressure level – A reliable predictor for human responses to impulse noise?	1993	D
Knauer RH	Autolärm schädigt Herz und Gefäße. Bluthochdruck-Koronare Herzerkrankung	1993	D
Griefahn B	Noise-induced responses and hypertension	1994	D

Evans GW; Hygge S; Bullinger M	Chronic noise and physiological stress	1995	D/USA
Orscheid J	Comment on the results of epidemiological noise effect studies	1995	D
Regecova V; Kellerova E	Effects on urban noise pollution on blood pressure and heart rate in pre-school children	1995	SI
Berg M van den	Noise management in the Netherlands	1996	NL
Jansen G; Schwarze S; Notbohm G	Noise induced hazards to health with special respect to the physiological noise-sensitivity	1996	D
Vögel R	Lärm fördert Herzinfarkt.	1996	D
Hecht K; Maschke C	Gesundheitliche Auswirkungen des Verkehrslärm – Nächtlicher Dauerstress	1997	D
Kunzmann B	Symposium: Health and risks due to noise. 10. February 1998 in Bonn	1998	D
Passchier-Vermeer W; Passchier WF	Environmental noise exposure 2	1998	NL
Pott F	Wenn bei Dauerkrach das Herz versagt. Neue Untersuchungen erhärten den Verdacht, daß Flug- und Verkehrslärm Krankheiten fördern	1998	D
Prasher D	Protection against noise : A European commission concerted action	1999	UK
Babisch W	Health effects of environmental noise – A status report	2000	D
Passchier-Vermeer W; Passchier WF	Noise exposure and public health	2000	NL
Weber T	Noise and cardiovascular risk	2000	D
Weber T	Environment and heart	2000	D

General European literature

AUTHOR	TITLE	YEAR	COUNTRY
Fine-Davis M; Davis EE	Predictors of satisfaction with environmental quality in eight European countries	1982	IRL
Lange-Asschenfeldt H	The Institute for Water, Soil and Air Hygiene of the Federal Health Office	1993	D
Wieczorek B	The objectives of noise control in future Europe	1993	D
WHO	Concern for Europe´s tomorrow	1995	EU
Muller H	The Green Book of the Commission of the European Union on the future noise protection policy	1997	D
Irmer VKP	Harmonisation of the European noise policy	1999	D
Irmer V	Position paper of the working group 1 of the European Commission on noise pollution parameters	2000	D
Irmer V	Noise abatement politics in Germany in European environment	2001	D
Mosdzianowski G	Noise control system – European standards for reduction of unfair competition	2001	D

Annex 2.3 Epidemiological data on traffic noise pollution in Northern Europe

Annoyance

AUTHOR	TITLE	YEAR	COUNTRY
Jonsson E; Kailand et al.	Annoyance reaction to traffic noise in Italy and Sweden	1969	S/I
Berglund B et al.	Relationship between loudness and annoyance for community sounds	1990	S
Berglund B; Lindvall T et al.	Adverse effects of aircraft noise	1990	S
Öhrström E; Rylander R et al.	Effects of noise during sleep with references to noise sensitivity and habituation	1990	S
Gjestland, et al.	Response to noise around Oslo Airport Fornebu	1990	NO
Rylander R; Dunt DR	Traffic noise exposure planning: a case application	1991	S/AUS
Nivison ME; Endresen IM	An analysis of relationship among environmental noise, annoyance and sensitivity to noise, and the consequences for health and sleep	1993	N
Öhrström E	Effects of low levels of road traffic noise during the night: A laboratory study on number of events, maximum noise levels and noise sensitivity	1995	S
Björkman M; et al.	Roar Traffic noise annoyance in relation to the individual noise dose	1998	S
Klaeboe R.	The combined effects of road traffic – implications for environmental guidelines	1998	S
Öhrström E; Skanberg A	Adverse health effects in relation to noise mitigation – a longitudinal study in the city of Göteborg	2000	S

Sleep

AUTHOR	TITLE	YEAR	COUNTRY
Arnberg PW et al.	Sleep disturbances caused by vibrations from heavy road traffic	1990	S
Berglund B; Lindvall T et al.	Adverse effects of aircraft noise	1990	S
Öhrström E; Rylander R et al.	Effects of noise during sleep with references to noise sensitivity and habituation	1990	S
Nivison ME; Endresen IM	An analysis of relationship among environmental noise, annoyance and sensitivity to noise, and the consequences for health and sleep	1993	NO
Öhrström E	Effects of low levels of road traffic noise during the night: A laboratory study on number of events, maximum noise levels and noise sensitivity	1995	S
Öhrström E; Agge A; Björkmann M	Sleep disturbance before and after reduction in road traffic noise	1998	S
Öhrström E; Skanberg A	Adverse health effects in relation to noise mitigation – a longitudinal study in the city of Göteborg	2000	S

Vegetative-hormonal reaction

AUTHOR	TITLE	YEAR	COUNTRY
Berglund B; Lindvall T et al.	Adverse effects of aircraft noise	1990	S

Annex 3. Conversion of level sizes

Traffic noise

Method 1

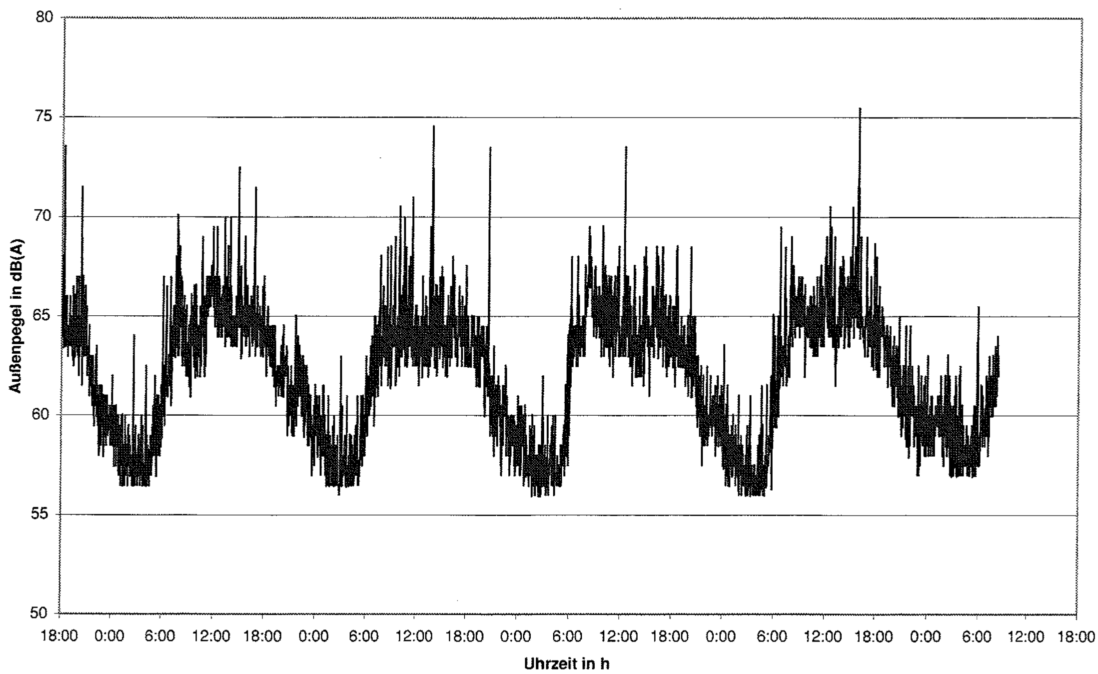
Was the equivalent continuous sound level not measured over usual times (6-22 h, 22-6 h, 23-7 h or over a period of 24 hours)? The sound level for the preferred duration was calculated with augmenters derived from measurements of two Berlin streets. For unusual durations used in the studies the noise level was calculated in the sample streets. The difference in the desired noise level, e.g. the 24h sound level, was used as an augmenter. The augmenters from the two different examples were averaged. The example streets were a strongly frequented and quieter (from a traffic point of view) urban street in Berlin. The equivalent continuous sound level was measured continuously every two minutes for more than 5 weekdays. The sound level courses were reproduced very well for the two streets every five days (see Fig. 21 in annex).

The augmenter was by the Leq,10-16h [Meijer, H. Knipschild, P. u. Sallé, H., 1985] approximately -2 dB.

For the measurement from 9-13 o´clock and from 17-20 o´clock the 24h sound level became around -1 dB corrects. [Aparicio-Ramon, D.V., et al., 1993]. For the night level a middle difference to the 24h sound level of 8dB was calculated.

The nocturnal sound level at measurement times from 0-1.30 o´clock and from 3.30-5.00 o´clock, [Belojevic,G., Jakovljevic, B. u. Aleksic, O., 1997] became calculated with an augmenter of +1 dB.

a)



b)

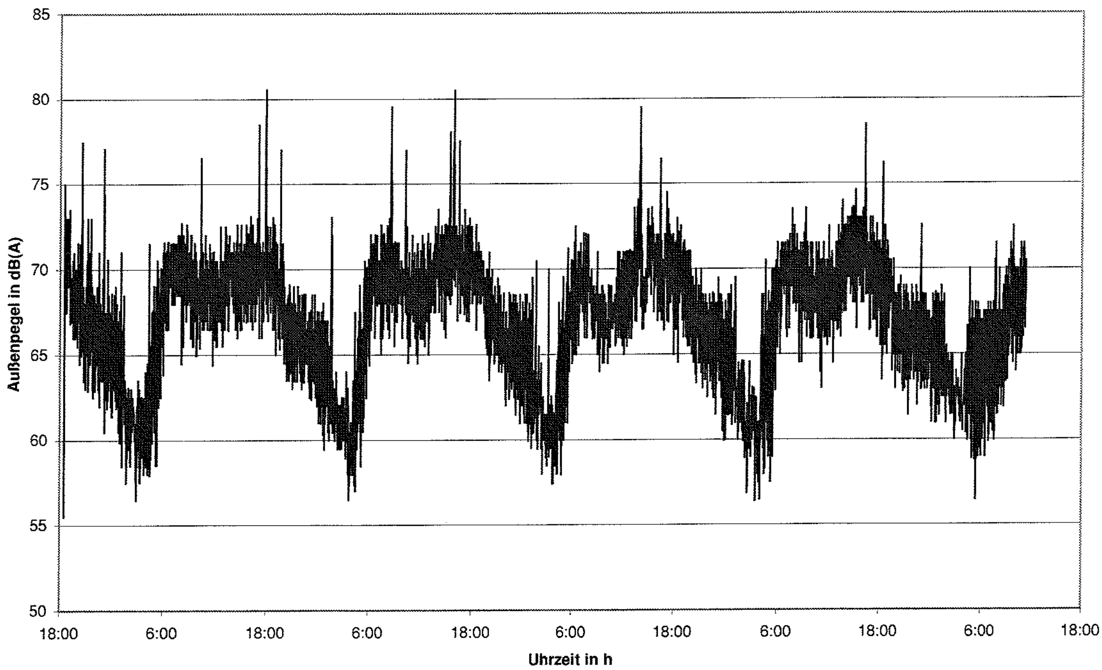


Fig. 21 and Fig. 22: Short time equivalent continuous sound level from 2 Berlin streets over 5 weekdays.

Method 2

The 24h sound level was calculated on the basis of the following formula:

$$L_{eq,24h} = 10 \cdot Lg \frac{1}{24} \cdot (16 \cdot 10^{\frac{Leq,16h}{10}} + 8 \cdot 10^{\frac{Leq,8h}{10}}) \quad \text{dB(A)} \qquad (1)$$

The difference between day and night levels was calculated with the following formulae and details in accordance with RLS 90:

equivalent continuous sound level $L_m^{(25)}$:

$$L_m^{(25)} = 37{,}3 + 10 \cdot \lg[M \cdot (1 + 0{,}082 \cdot p)] \quad \text{dB(A)} \qquad (2)$$

Table 25: Traffic power M in cars per hour and portion p (more than 2.8 t of permitted total weight) in %

Type of street		day (6:00 -22:00 hours)		night (22:00-6:00 hours)	
		M	p	M	p
		Cars per hour	%	Cars per hour	%
3	Country and municipality connecting roads	0.06 DTV	20	0.008 DTV	10
4	Local streets	0.06 DTV	10	0.011 DTV	3

For street type no. 3 the results were:

$$L_m{}^{(25)}{}_{,Tag} = 37{,}3 + 10 \cdot \lg 0{,}06 + 10 \cdot \lg(1 + 0{,}082 \cdot 20) + 10 \cdot \lg DTV = 29{,}3 + 10 \cdot \lg DTV$$

$$L_m{}^{(25)}{}_{,Nacht} = 37{,}3 + 10 \cdot \lg 0{,}008 + 10 \cdot \lg(1 + 0{,}082 \cdot 10) + 10 \cdot \lg DTV = 18{,}9 + 10 \cdot \lg DTV$$

=> $L_m{}^{(25)}{}_{,Tag}$ - $L_m{}^{(25)}{}_{,Nacht}$ = 10 dB

For street type no. 4 results:

$$L_m{}^{(25)}{}_{,Tag} = 37{,}3 + 10 \cdot \lg 0{,}06 + 10 \cdot \lg(1 + 0{,}082 \cdot 10) + 10 \cdot \lg DTV = 27{,}7 + 10 \cdot \lg DTV$$

$$L_m{}^{(25)}{}_{,Nacht} = 37{,}3 + 10 \cdot \lg 0{,}011 + 10 \cdot \lg(1 + 0{,}082 \cdot 3) + 10 \cdot \lg DTV = 18{,}7 + 10 \cdot \lg DTV$$

=> $L_m{}^{(25)}{}_{,Tag}$ - $L_m{}^{(25)}{}_{,Nacht}$ = 9 dB

For fields with different traffic loads, the mean average value of the differences calculated was used for the estimate. It resulted in:

$L_{eq,16h} = L_{eq,8h} - 9{,}5dB$:

$L_{eq,24h} = L_{eq,16h} - 1{,}5dB$ dB(A) (3)

Method 3

Formula (2) is used for conversion of the night level:

$L_{eq,8h} = L_{eq,24h} - 8dB$ dB(A) (4)

The nocturnal sound levels by [Öhrström, E.; Björkman, M. u. Rylander, R., 1990] were thus calculated.

[Öhrström, Agge u. Björkman, 1998]:

Data: DTV= 24600 cars per 24h, p_{day}=17,8%, p_{night}=0,5%

The difference between day and night sound levels was calculated with category 4 and with category 3. The average value resulted in 12 dB. For the control area the difference to the $L_{eq,\ 24h}$ were calculated at 8 dB.

[Arana,M. u. Garcia, A., 1998]:

The different examination areas were subdivided into three noise load classes and the following correction factors were calculated.

Strongly loaded field ($L_{eq,24h}$=73 dB(A)): 6 dB

Field charged low ($L_{eq,\ 24h}$ =58,4 dB(A)): 13 dB

Three averagely charged fields ($L_{eq,\ 24h}$ between 64 and 69 dB(A)): 8 dB

Aircraft noise

Method 4

By Kastka et al. [1996] the sound levels Leq,16h, Leq,18h were converted into a Leq,24h. The differences between Leq,16h, Leq,18h to the Leq,24h were calculated on basis of the German DIN 45 643 part 1. For the calculation a maximum sound level of 70 dB(A) as well as a 10 dB down-time of 20s was adopted (see Table 26).

Table 26: Augmenters for flight noise

about 143,000 flights in 1987 and 1995								
392/day								
for16h-measurement								
Assumption: 10% at night, 90% in the day								
day	night		LAs max	dLax	Lax	Leq,day	Leq,night	Leq24h
353	39		70	13,0	83,0	60,9	54,3	59,6
				(Assumption: t10=20s)				
						Difference Leq24,Leq16:		**-1,3**
Assumption: 5% at night , 95% in the day								
day	night		LAs max	dLax	Lax	Leq,day	Leq,night	Leq24h
372	18		70	13,0	83,0	61,1	51,0	59,6
				(Assumption: t10=20s)				
						Difference Leq24,Leq16:		**-1,6**
Assumption: 15% at night, 85% in the day								
day	night		LAs max	dLax	Lax	Leq,day	Leq, night	Leq24h
333	59		70	13.0	83.0	60.6	56.1	59.6
				(Assumption: t10=20s)				
						Difference Leq24,Leq16:		**-1,1**
Assumption: 20% at night, 80% in the day								
day	night		LAs max	dLax	Lax	Leq, day	Leq, night	Leq24h
314	78		70	13.0	83.0	60.4	57.3	59.6
				(Assumption: t10=20s)				
						Difference		**-0.8**

						Leq24,Leq16:		
for 18h-measurement								
Assumption: 10% at night, 90% in the day								
day	night		LAs max	dLax	Lax	Leq, day	Leq, night	Leq24h
353	39		70	13.0	83.0	60.4	55.6	59.3
				(Assumption: t10=20s)				
						Difference Leq24,Leq18:		**-1.1**
Assumption: 5% at night, 95% in the day								
day	night		LAs max	dLax	Lax	Leq, day	Leq, night	Leq24h
372	18		70	13.0	83.0	60.6	52.2	59.1
				(Assumption: t10=20s)				
						Difference Leq24,Leq18:		**-1.5**
Assumption: 15% at night, 85% in the day								
day	night		LAs max	dLax	Lax	Leq, day	Leq, night	Leq24h
333	59		70	13.0	83.0	60.1	57.4	59.4
				(Assumption: t10=20s)				
						Difference Leq24,Leq18:		**-0.7**
Assumption: 20% at night, 80% at day								
day	night		LAs max	dLax	Lax	Leq, day	Leq, night	Leq24h
314	78		70	13.0	83.0	59.9	58.6	59.5
				(Assumption: t10=20s)				
						Difference Leq24,Leq16:		**-0.4**
Complete correction of 16 or 18h-sound level to 24h-Leq **-1 dB**								

Jonckheere [1989] published a conversion formula from the NNI into L_{dn}:

$$L_{dn} = 0{,}850 \cdot NNI + 32{,}01$$

For calculating the $L_{eq,24h}$ from the L_{dn} the knowledge of the difference between day and night level is necessary, because by the L_{dn} the night level was increased by 10 dB.

Table 27: Augmenters for flight noise

Details								
Day : 93%		Night : 7%			357	Flight events per day, approx.		
332	7-22h	25	22-7h					
Assumption:								
averaged maximum sound level: 70 dB(A)								
t10=20s								
			LAs max	dLax	Lax			Leq24h
			70	13.0	83.0			59.2
						Leq, day 7-22h	Leq, night 22-7h	Ldn
						60.9	51.9	61.3
						Difference Leq,24h-Ldn:		**-2.1**
Correction of Ldn to Leq,24h: about **-2 dB**								

Using Garcia and Faus [1987] the published NEF can be converted to the L_{dn} with the following formula (Schaefer, 1978):

$$L_{dn} = NEF + 35dB$$

With the calculated difference of 2 dB between Leq,24h and Ldn [Jonckheere et al, 1987] results the second formula:

$$L_{eq,24h} = NEF + 33dB$$

References

Chapter 1: Health effects

Cannon, W.B. (1928): Neural Organisation of emotional expression. In: Mirchinson C. (eds.) Feeling and Emotions, Worcester

Cannon, W. B. (1929): Bodily Changes in Hunger, Pain and Rage. Appleton, New York

Felker B. und J.R. Hubbard (1998): Influence of mental stress on the endocrine system. In: Hubbard JR, Workman EA, editors, Handbook of stress medicine - An organ system approach. CRC Press, S.69-86

Graff, C., F. Bockmühl, V. Tietze (1968): Lärmbelastung und arterielle (essentielle) Hypertoniekrankheit beim Menschen. In: S. Nitschkoff, G. Kriwizkaja: Lärmbelastung, akustischer Reiz und neurovegetative Störungen. Georg Thieme, Leipzig

Griefahn, B. (1985): Schlafverhalten und Geräusche. Enke Verlag Stuttgart

Hecht, K. (1992): Besser schlafen, schöner träumen. Südwest Verlag

Hecht, K. (1998): Neugeboren durch gesunden Schlaf. Cormoran Verlag, München

Hecht, K. H.-U. Balzer (2000): Chrono- Psycho- Biologische Regulationsmedizin und ihre Bedeutung für die Katastrophenmedizin. In: Hecht, K. H.-U. Balzer (Hrsg.): Stressmanagement, Katastrophenmedizin, Regulationsmedizin, Prävention. Pabst-Verlag Lengrich, Berlin, Riga, Rom, Wien, Zagreb, 109-133

Ising, H. (1993): Comparison of acute reactions and long-term extra-aural effects of occupational and environmental noise exposure. Noise as a Public Health Problem, (3), 280-287

King, M. G., A. J. Husband (1996): Konditionierung immunologischer Funktionen. In: M. Schedlowski, U. Tewes (Hrsg.): Psychoimmunologie. Spektrum, Akademischer Verlag, Heidelberg, Berlin, Oxford, 537-560

Lercher, P. (1996): Environmental noise and health: An integrated research perspective. Environmental International 22 (1), 117-129

Lindvall, T. and E.P. Radford (1973): Measurement of annoyance due to exposure to environmental factors. Environ. Res. 6, p.1-36

Lindsley, D.B. (1951): Emotion. In: S.S. Stevens (Eds.): Handbook of Experimental Psychology, New York, 1951

Maschke, C., Breinl, S., Grimm, R., Ising, H. (1992): Der Einfluß von Nachtfluglärm auf den Schlaf und die Katecholaminausscheidung. Bundesgesundheitsblatt 35119-122

Maschke, C., D. Arndt, H. Ising, G. Laude, W. Therfelder; S. Contzen (Hrsg.) (1995): Nachtfluglärmwirkungen auf Anwohner. Schriftenreihe des Vereins für Wasser-, Boden- und Lufthygiene 96; S. 1-140

Maschke, C., H. Ising, K. Hecht (1997a): Schlaf-nächtlicher Verkehrslärm-Streß-Gesundheit: Grundlagen und aktuelle Forschungsergebnisse, Teil I: Grundlagen. Bundesgesundheitsblatt 1; S. 3-10

Maschke, C., H. Ising, K. Hecht (1997b): Schlaf-nächtlicher Verkehrslärm-Streß-Gesundheit: Grundlagen und aktuelle Forschungsergebnisse, Teil II: aktuelle Forschungsergebnisse. Bundesgesundheitsblatt 3; S. 86-95

Maschke, C., T. Rupp, K. Hecht (2000): The influence of stressors on biochemical reactions - A review of the present scientific findings with noise. Int. J. Hyg. Environ. Health 203, 45-53.

Mc Lean, P.D. (1949): Psychosomatic disease and the visceral brain. Psychosom. Medicine 11, 338-353

OECD (1991): The state of the environment. Paris

Rechtschaffen, A., A. Kales (1968): A manual of standardized terminology, techniques and scoring system for sleep stages of human subject. Public Health Service, U.S. Government Printing Office, Washington D.C.

Passchier-Vermeer, W. (1993): Noise and Health. The Hague: Health Council of the Netherlands, Publication no. A93/02E

Pawlow, J. P. (1927): Vorlesungen über die Arbeit der Großhirnhemisphären (russ.). Deutsche Fassung in: J. P. Pawlow: Sämtliche Werke, Bd. IV. Akademie-Verlag, Berlin, 1953

Simonov, P. W. (1975a): Widerspiegelungstheorie und Psychophysiologie der Emotionen. Verlag Volk und Gesundheit, Berlin

Traue, H.C. (1999): Emotion und Gesundheit. Spektrum, Akademischer Verlag, Heidelberg, Berlin

Chapter 2.1: Southern Europe

Alvarado J et al. (1994) Behaviour and performance of scholars in a very noisy school. 11th International Fase Symposium. Valencia.

Barrigón Morrillas JM., et al. (1999)Estudio preliminar del ruido ambiental en la ciudad de Cáceres. Tecniacústica Avila.

Barti Domingo R. (1995) Ruido de tráfico en ciudad. Propuesta de nueva normativa. Tecniacústica. La Coruña.

Bento Coelho J., Palma M., Almeida A.(1999) Novo Aeroporto de Lisboa- Estudio de ruido. Tecniacústica - Avila.

Burgui M., Vela Pons A. (1992) Ruido de tráfico interurbano. Variables y predicción. Revista de Acústica. 3-4 (23): 15-17.

Chana L., et al (1995) Niveles sonoros ambientales en la ciudad de Madrid. Tecniacústica. La Coruña.

Garabedian E. (1999) Effets du bruit sur la santé de lènfant. Arch Pédiatr 6 suppl 2: 286-8.

García A., Llopis González A. (1989) Alteraciones del sueño producidas por el ruido ambiental. Gaceta Sanitaria. 12 (3): 421-6.

García A. (1991) La respuesta subjetiva al ruido ambiental. Revisión de diferentes estudios realizados en la Comunidad valenciana entre los años 1981 y 1991. Revista Acústica 22 (1-2): 29-33.

García A. (1995) Predicción de niveles de ruido ambiental producido por el tráfico rodado en zonas urbanas. Tecniacústica. La Coruña.

García A et al.(1999) Evaluación de la molestia producida por el ruido ambiental. Tecniacústica . Avila.

Guijarro D., Llorens D., Linares E., Rodrigo D., Albiach M., Sánchez P., García A., García AM. (1996) Efectos del ruido ambiental sobre el sueño de los residentes en zonas urbanas. Tecniacústica-Barcelona.

Herranz K., López Barrio I., Carles JL. Respuesta subjetiva de molestia al ruido interior producido por los vecinos. This paper is part of a research programme supply by CICYT (n. SEUI PB0215).

López Barrio I., Herranz Pascual K. (1991) Efectos del aislamiento acústico de una escuela en las respuestas de los profesores al ambiente de ruido I y II. Conference: Noise in Metropolitan Cities. Madrid.

López Barrio I., Carles JL., Herranz K. (1992) The effect of a noise abatement program on the attention capacity and reading ability of school. 14th International Congress on Acoustic. Beijing, China.

Martimportugués Cl. Efectos en salud: el ruido y el hacinamiento. Doctoral Thesis.

Morales Suárez Varela et al. (1992) Evaluation of the Environmental Noise Effects on the population of the Historical Centre of Valencia. Rev San Hig Púb 66 (3.4): 240-244.

Pons Espí., Santiago Páez J. (1993)Control de ruido de ferrocarril mediante apantallamiento acústico. Un caso práctico. Tecniacústica Valladolid

Romero González e.,Ronda Hernández F. (1995) El ruido en los estudios de impacto ambiental. Tecniacústica. La Coruña.

Sanz S., García AM., García A. (1993) Los efectos del ruido de tráfico sobre el rendimiento de los alumnos en colegios de enseñanza primaria. Tecniacústica – Valladolid.

Tobías A., Díaz J., Saez M., Alberdi JC. Use of Poisson Regression and Times Series Analysis to evaluate the short-term effects of environmental noise levels on health in Madrid, Spain. In press.

Vogiatzis C. (1991) Traffic noise maps in Greek cities- Acoustic measurements and evaluation. Noise in Metropolitan Cities. Madrid.

Chapter 2.3: Northern Europe

WHO Guidelines (www.who.int/peh/noise)

Swedish Department of Social Health, General Advise, SOSF6 1996

Action Plan Towards Noise, SOU 1993:65

Adverse Health Effects in Relation to Noise Migration – a longitudinal study in the city of Göteborg. In proceedings "Inter Noise 2000". Cassereau (Ed.) August 27-30, 2000, Nice, France

Effekter av exponering för buller och vibrationer från tågtrafik – undersökning i 15 tätorter. E Öhrström, A-B Skånberg

Konsekvenser va Lundbytunneln

Omgivningsbullers effekt på människan. E Öhrström, SOU 1993:65 Annex

Undersökning av samband mellan störningar av buller, neurofysiologisk känslighet, subjektiv bullerkänsla samt andra individvariabler. E. Öhrström, M. Björkman, B Levin, R Rylander, U Åhrlin)

Chapter 3: Evaluation of the existing data pool

Aparicio-Ramon, D.V. et al. (1993): Subjective Annoyance caused by Environmental Noise, J. of Env. Pathology, Toxicology and Oncology, 12(4), p 237-243

Arana, M. u. Garcia, A. (1998): A Social Survey on the Effects of Environmental Noise on the Residents of Pamplona, Spain, Applied Acoustics, V. 53, N. 4, p 245-253

Belojevic, G.; Jakovljevic, B. u. Aleksic, O. (1997): Subjective reactions to traffic noise with regard to some personality traits, Environmental International, 23(2), p 221-226

Björkman, M. et al., (1998) : Road traffic noise annoyance in relation to the individual noise dose, In: Noise Effects '98 - 7th int. Congress on Noise as a public Health Problem, Sydney, Australia, Congress Proceedings V. 2, p 460-463

Conzelmann-Auer, C. et al. (1993): Die Wahrnehmung der Verkehrslärmimmissionen im Kanton Basel-Stadt im Vergleich zu den erhobenen Lärmmesswerten, Soz. Präventivmed., 38, p 231-238

de Jong, R.G. ; Jurriens, B. u. Groot, B. (1992) : Geluidhinder in relatie tot gezondheid, Projectbureau Noordrand Rotterdam

Felscher-Suhr, U. et al. (1996): Eine methodologische Studie zur aktuellen Erfassung von Alltagstätigkeiten und deren Störungen durch Umweltlärm, Zeitschrift für Lärmbekämpfung, 43, p 61-68

Garcia, A. u. Romero, J. (1987): Road traffic noise and sleep disturbance, In: National Conference on Noise-Control-Engineering, NOISE-CON `87, Noise Control Foundation, Poughkeepsie, NY (USA), p 461-464

Garcia, A. et al. (1990): Community Response to Environmental Noise in Valencia, Environment International, 16, p 533-541

Garcia, A.; Faus, L.J. u. Garcia A.M. (1993): The community response to aircraft noise around six Spanish airports, Journal of Sound and Vibration, 164(1), p 45-52

Gjestland, et al. (1990) : Response to noise around Oslo Airport Fornebu, Trondheim : Elab-Runit Sintef Gruppen, Acoustics Research Center, Report STF 40 A90189

Griefahn, B. (1986): Grenzwerte nächtlicher Belastbarkeit durch Straßengeräusche, Applied Acoustics 19, p 265-284

Notice to the reader

Extensive information on the European Union is available through the EUROPA service at internet website address - http://europa.eu.int/

The internet web site address for the traffic noise pollution 2001 project can be found at:
www.tu-berlin.de/bzph/tnp2001

Further information on DG Health and Consumer Protection can be found at the following web site:
http://europa.eu.int/comm/dgs/health_consumer/index_en.htm

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