Dillon Corcoran

From: Liam O'Gradaigh <logradaigh@hotmail.com>
Sent: Monday 23 December 2024 16:36
To: Appeals2
Subject: PL06F.314485 (F20A/0668)
Attachments: Submission_ABP_DraftDecision_LiamOGradaigh_20-12-2024.pdf; 20240624-ppt-Hahad.pdf; advisory-report-the-influence-of-night-time-noise-on-sleep-and-health.pdf; planning-enforcement-complaint-form-65-Flights-summer.pdf; PENF_0133_2023 S153.pdf; PENF_0134_2023 S154 Enforcement Notice.pdf; ENF_24-263_Dublin_Airport_32m_cap.pdf; Transportation_Noise_Pollution_and_Cardiovascular_Health.pdf; Noise_causes_cardiovascular_disease.pdf; Daytime_vs_Nighttime_effects_of_aircraft_noise.pdf; enhealth-guidance-the-health-effects-of-environmental-noise.pdf; Basner_aircraft_noise_exposure.pdf; Basner_Environmental_Noise_and_Effects_on_Sleep.pdf; Basner_effects_on_sleep.pdf; Tech 11 2010 Good practice guide on noise.pdf; Dublin_Airport_Noise_Medical_Report.pdf

Dear An Bord Pleanála,
Please find attached my submission on the draft decision by the Board in relation to PL06F.314485.
I made previous submissions to the Board and do not need to pay a further fee.

Please acknowledge receipt of this submission.

Many thanks
Liam

Liam O'Gradaigh
Ward Cross
The Ward
Co. Dublin

The Secretary
An Bord Pleanála
64 Marlborough Street
Dublin 1
D01 V902
23rd December 2024

RE: DRAFT DECISION BY AN BORD PLEANALA ON PLANNING APPLICATION F20A/0668

Dear Sir/ Madam,

I welcome the opportunity to make a submission on the draft decision by An Bord Pleanála, dated September 17th, 2024. I note the information in the draft decision is very complex and one that should have been facilitated with an Oral Hearing. The Board does not have the relevant expertise to understand the complex details of aircraft noise and an Oral Hearing would have provided an opportunity to clarify many of the issues. This submission highlights a number of serious deficiencies with the proposed application and as a result the permission should be refused. The daa has carried out unlawful development breaching the passenger cap in 2019, 2023 and in 2024. The daa have never respected the 65 nighttime flight limit which ironically is one of the conditions that they are trying to amend in this Relevant Action. The daa have known about PFAS contamination at the time the North Runway was being constructed and decided to withhold this information from the authorities and literally buried the contaminated soil on site. This PFAS contamination has never been screened in any environmental assessment by the daa and has not been assessed in this application. All projects and impacts need to be assessed for cumulative and in-combination effects. In fact, the whole North Runway project has never had a full AA.

There are major concerns with the AA screening in this application and in particular the failure of the Board's ecologist to examine appellant's submissions. Surveys are out of date, lack of cumulative and in-combination project screening, failure to screen for the effects on the Red Kite, failure to understand the real noise levels at the SPAs and SACs along the Dublin Coast.

The daa have failed to show a need for this development. Their own data shows they can achieve 40mppa by 2034 without the Relevant Action. ANCA and the Board have failed to take Health costs into account. The daa provided a sub-standard assessment on awakenings. Awakenings have been assessed at key receptors under both the

North and South Runways and the proposal fails to achieve less than one additional awakening per night on average. The awakenings criteria can only be achieved by a complete ban on nighttime flights. The Board's movement limit doesn't address all awakenings, and the Board has not provided any mitigation measures for those still impacted by awakenings. Insulation is not the panacea that the daa and ANCA claim. A 20k euro grant to insulate bedrooms is an insult to the residents impacted. It doesn't matter what happens in other jurisdictions, especially the UK, which is no longer in the EU, the residents have the right to a good night's sleep and the right that their health is not impacted. EU598/2014 is all about applying the Balanced Approach, but in this application to date there is no balance. Health costs have not been taken into account. The Board needs to revisit the insulation scheme and its adequacy as there are some dwellings not adjacent to the flight paths that would benefit from it. But this is not the case for dwellings immediately adjacent to the airport and under the flight paths.

It is very evident that the Noise Abatement Objective has been breached in 2022 and again in 2023, with no repercussions from ANCA. The noise has increased for those residents exposed to the higher contours of noise. It is only at the lower noise contours where the noise has reduced. But these lower noise contours are where the densely populated areas in Dublin are and so skew the results. ANCA seem happy that the number of people affected from all noise has reduced but fails to address the real issue of increasing noise on those already severely impacted by noise. It is very clear that noise is increasing at Dublin Airport and not reducing. It is pure fiction that quieter aircraft will reduce noise levels when the aircraft movements are increasing. Quiter aircraft have done nothing to reduce noise over the 2 Rounds of the End and there's evidence that it will lead to lower noise levels in the future, with increasing aircraft movements. This is a national scandal, and the lives and health of Fingal and Meath residents are being disregarded in the name of aviation growth. The daa have never provided a business plan to properly address the impacts on residents. They failed to engage with Community groups on the flight path issue stating they cannot discuss them while enforcement proceedings are ongoing. It is crucial that the Board makes a decision on the validity of the flight paths. The Planning Authority has had enforcement proceedings open on the flight paths since 2022 but has been waiting for the Board to adjudicate. From the draft decision, the Board has not come to a conclusion and appears to be passing the issue back to the Planning Authority. Condition 1 of 2007 still applies and the current flight paths are in violation of condition 1. It has been shown that the airport can operate in different runway configurations such as Dependent mode which doesn't require divergence. This alternative has never been submitted for discussion. In addition, no alternative has been proposed to allow for respite from aircraft noise as is in place at Heathrow. At Heathrow the runways alternate at 3pm to offer respite. At Dublin Airport the aim appears to inflict as much damage as possible on the populations under the North Runway flight paths from 6am to 12 midnight without any respite.

The remainder of this submission goes into further detail on the serious issues with this proposed development. I also endorse the submission from the St Margarets The Ward Residents Group. I plead with the Board to refuse permission but in the event that some sort of permission is granted, I ask that the Board put in clear and concise

conditions. The daa have no respect for the Board and have found ways to create legal ambiguity with the previous conditions on the North Runway planning. In 2007 the Board members went against the Inspector and granted permission for the North Runway and imposed two conditions to alleviate the Significance issue. But as soon as permission was granted the daa started to work on ways to get rid of these conditions and effectively ignore them. At this point in time the daa are above the Planning bodies in this country. They have no respect for the Board and will ignore whatever the Board tries to impose on them. The Board needs to assert its authority or else its very existence and future will be called into question.

Yours Sincerely

_____

Liam O'Gradaigh

Flight Paths:

During this process, there have been effectively 3 separate EIARs submitted by the daa. The last Supplementary EIAR included significant changes to the previous EIARs, mainly that whole new flight paths have been submitted. This was the third revision of the EIAR, and one must ask the Board how many chances an applicant gets. In previous submissions to the Planning Authority, ANCA and the Board, it has been highlighted that the flight paths in operation are not the ones used in the original planning permission of 2007. In 2007 they were based on straight out flight routes and all the environmental assessments and baselines were based on these straight-out routes. In 2018, Fingal County Council signed off on compliance for Condition 7 on planning permission in relation to the dwelling insulation scheme. Fingal County Council employed AWN Consulting to review the insulation scheme, and no issues were raised at that time in relation to the noise contours as they were based on straight-out flight paths. In the intervening years, the daa decided they wanted to use divergent flight paths. They presented a 15/75-degree option in a consultation in 2016. At this point in time the daa intended to submit a revised EIS and planning application to the Board. I have received this draft EIS via an AIE request which was initially refused but eventually granted by the OCEI Commissioner. However, the EIS approach was dropped in favour of the Relevant Action approach as part of the Aircraft Noise (Dublin Airport) Regulation Act 2019. But somewhere along the way the daa forgot to include flight paths changes in their planning application. Nowhere in the planning notice does it state that the daa wish to apply for new flight paths.

They began operations on the North Runway in August 2022 and immediately it was noticeable to the public that the flight paths were incorrect. It took the daa 2 weeks before they made contact with the IAA to understand what had happened. Then in February 2023 they revised their flight paths once more. These revised flight paths were again subject to no public consultation or planning permission. These too were never environmentally assessed. But still these flight paths did not adhere to the ones that were environmentally assessed in 2004-2007 and which formed part of Condition 1 of planning. Enforcement investigations have been underway with Fingal County Council for over 2 years now and it's evident that they do not want to rule on this and are leaving it up to the Board to decide. Unfortunately, the Inspector has not made any decision on the flight paths, and we are left in limbo.

Flight paths are a fundamental part of this application, and the Board must adjudicate on them. Failure to do so could set a precedence where flight paths could be changed at any time by the daa without any proper planning consent. The Board must take cognisance of Condition 1. Condition 1 is still valid and the daa never applied to change it. Therefore, the flight paths need to be refused and the daa ordered to apply to change Condition 1. The flight paths are also fundamental to the issue of Significance. Significance was never assessed in the planning of 2007 and the Board's Noise expert and Inspector concluded that planning for the North Runway should be refused due to lack of evidence of Significance. We now have a situation where the Relevant Action has not been compared to 2007 in terms of Significance and therefore the application fails the basic Significance criteria. The Inspector has not grasped the severity of the lack of Significance analysis between the 2007 planning application and the Relevant Action.

In the Infrastructure Application (F23A/0781), the Planning Authority requested a response to the following question which can be viewed on page 359 of the CE's Order of 16th Feb 2024, https://planningapi.agileapplications.ie/api/application/document/FG/907689:

> "*The applicant is invited to provide analysis with narrative explaining the variation over time, of previously modelled aircraft noise contours for Dublin Airport. The analysis should be accompanied by an overlay graphical representation of noise modelling prepared and presented as contours for the currently proposed development shown with each of the following previously presented contours:*
>
> *1) the North Runway application (December 2005 EIS),*
>
> *2) the consented North Runway (EIS Addendum 9th August 2007)*
>
> *3) the modelling agreed for operation of the noise mitigation schemes under that permission (2016)*
>
> *4) the Airport Noise Zones in the Fingal Development Plan 2023. The methodological differences between the various contours and the reasons why they are not directly comparable should be noted.*"

The answer to Question #6 is in the doc *'Part 1 - RFI Response Report B Response to RFIs'*, on page 76 which is page 56 of the Coakley O'Neill report:

https://planningapi.agileapplications.ie/api/application/document/FG/1067909

Coakley O'Neill discuss the evolution in noise contours since 2004:

North Runway Dec 2004:

> "*The flight routes assumed that the North Runway tracks would replicate those on the South Runway. These assumed aircraft turned after a* ***straight segment of around S nm*** *from the end of the runway*"

Noise Mitigation 2016 (insulation scheme compliance):

> "*The flight routes assumed that the north runway tracks would replicate those on the south runway. These assumed that 25% of aircraft turned after a straight segment of around 5 nm from the end of the runway, with the remaining 75% turning earlier, around 2 nm from the end of the runway. This was based on an analysis of a sample of radar flight tracks*"

IA EIAR Dec '23:

> "*The flight routes were based cm an analysis of actual radar tracks. For the South Runway these were similar to previous assumptions.* ***For the North Runway this meant an initial 30 degree right turn shortly after the end of the runway.*** *After this initial turn the routes are similar to previous assumptions.*"

"This response is written in the context of the Board Inspector's findings in her assessment of the North Runway Relevant Action (NRRA), ABP Ref. No. ABP-314465-22 (F20A/0668), which stated that:

> *"the Board will note that the flight patterns submitted in the applicant's supplementary information and included far the purpose of the proposed scenario of the EIAR,* ***differ to those submitted in the original EIS*** *for the NR application. The Board will note that the flight patterns submitted to the planning authority for the original Relevant Action also differed from those submitted with the original EIS for the NR application* ***The main difference between the revised EIAR and the amended supplementary EIAR is the divergence north from the NR, earlier than previously indicated in the revised EIAR permitted by the planning authority.'"***

So here for the very first time since the North Runway opened, we have Coakley O'Neill on behalf of the daa holding their hands up in an official submission document, acknowledging and agreeing with the Board's Inspector that the current flight paths are different than originally submitted and planned for. This has serious implications, and this has been pointed out on numerous times to the Planning Authority, ANCA and An Bord Pleanála during this Relevant Action planning application process. Therefore, this is an admittance of Unauthorised Development by the applicant and the Board have no alternative but refuse planning permission or request the applicant apply for retention or substitute consent.

Significance formed a major part of Mr Rupert Thornely-Taylor's evidence to the Board back in 2004-2007. Mr Thornely-Taylor was very clear that Significance was not addressed in the planning for the North Runway, and he recommended refusal on that basis. The Inspector agreed with Mr Thornely-Taylor and recommended refusal. The Board went against the recommendation of the inspector and inserted Conditions 3(d) and 5 to alleviate the Significance problem. However, Significance has not been addressed in this Relevant Action application by comparing the 'Proposed' scenario to what was granted in 2007. Permission was granted for straight out flight paths in 2007 and the Relevant Action has never compared any Proposed scenario with straight out flight paths. Therefore, Significance has not been addressed. The Board is reminded that the Relevant Action just concerns Condition 3(d) and 5 of 2007 and that Condition 1 still remains in force. The Relevant Action does not replace the planning of 2007 but just amends those 2 conditions. Therefore, it is very clear that Significance has not been assessed correctly now, as was the case in 2007, and the Board cannot approve the application with an invalid assessment. The lack of a proper Significance assessment is contrary to the EIAR Guidelines.

If the Board does approve the Relevant Action, the Board must state clearly in their decision that the **flight paths have not been approved by the grant of approval** and that any future flight path changes must go through proper planning and environmental assessment.

Awakenings:

Awakenings have been central to the Vanguardia report and the Inspector's draft report. Submissions have been made to the Board that the awakenings assessment provided by the daa fell very short of that requested by the Board. The daa provided no maps showing the areas impacted by 1, 2 and 3 awakenings.

However, an assessment has been provided by Suono based on the "*WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep*" by Basner and McGuire. The Suono report forms part of the submission by the St Margarets The Ward Residents Group. The Board should be mindful that the residents have had to pay for such an assessment as a proper assessment was not carried out by the daa as requested by the Board.

In the Suono assessment, 5 receptors were chosen, which are daa NMT locations located under the North and South Runway flight paths, and the awakenings calculated for each receptor based on the 2025 Proposed scenario. The assessment calculated awakenings using an external to internal adjustment of 15dB, 21dB and 22dB which allows for insulation. The results are provided in Table 1 of Suono's report:

Table 1 Calculated additional awakenings per night

Annual Average Glazing Reduction	NMT26	NMT28	NMT1	NMT2	NMT20
15 dB	1.8	1.9	0.6	3.0	2.6
21 dB	1.3	1.3	0.5	2.1	1.7
22 dB	1.3	1.3	0.5	2.1	1.7

The results of the assessment show that only NMT1 has less than 1 awakening. NMT1 is located at the Bay Lane and under Westerly departures on the South Runway. With the 2025 Proposed scenario there are very few departures off the South Runway and therefore the awakenings are less than 1. But for all other 4 receptors the awakenings are in excess of 1 awakening on average per night, even with insulation added. This proves that insulation is not the solution for the 2025 Proposed scenario and even with insulation the health of a significant number of residents in Fingal cannot be protected and the scenario fails the awakenings assessment.

NMT2 and 20 are located under the South Runway Easterly arrivals flight paths which traverses the highly populated area of Portmarnock. Even if the dwellings were insulated, the residents of Portmarnock would be subjected to more than 2 awakenings per night on average. This is extremely damaging to Human Health as has been pointed out by Mr Fiumicelli and by the submissions of Dr John Garvey.

The only solution is a complete ban on nighttime flights or a vast reduction in nighttime movements as proposed by the Board in their draft decision. If the Board does decide to grant permission for the Relevant Action with a restricted movement limit such as 13000, the Board must make allowance for those properties where more than 1 awakening would still occur. These dwellings must be offered Voluntary Purchase, relocation or enhanced insulation to protect their health. The Board are very clear in

their draft decision about the health impacts of awakenings and therefore the Board must be cognisant of its duties to protect Human Health.

Population Datasets:

In section 13B.4.1 of Appendix 13 of the Relevant Action Supplementary EAIR from September 2023, it states:

> "*Dwelling data has been acquired from GeoDirectory for **2019 Q2**, which was the dataset utilised in the original EIAR. The same dataset has been used for all assessment scenarios in this EIAR Supplement for consistency.*"

However, a later GeoDirectory **2023 Q3** dataset exists and has been used in the Infrastructure Application (F23A/0781).

ANCA have made it clear to the daa on numerous occasions that the most recent population datasets should be used for compliance with the NAO.

The Relevant Action Supplementary EIAR from September 2023 and the Infrastructure Application from December 2023 used different population datasets to calculate the population exposed to >55dB Lnight. The Relevant Action's assessment greatly underestimates the populations exposed to >55dB Lnight in comparison to the Infrastructure Application.

It is incumbent on the Board to request the daa to repeat the analysis of the populations exposed to >55dB Lnight using the **2023 Q3 dataset** as it's obvious that using the 2019 Q2 dataset has led to a misleading lower figure than the true figure. The daa's assessment contravenes the NAO requirements on population datasets and are out of date.

36m Planning Application:

On Friday December 20th 2024, the daa lodged a planning application to increase passenger numbers to 36m without any infrastructure changes. The application is denoted by F24A/1178E).

In Fingal's press release, https://www.fingal.ie/news/planning-application-raise-passenger-capacity-dublin-airport-received, they state that "*There were no pre-planning meetings between the Planning Authority and daa prior to the submission of this application*". This is very worrying that the daa didn't seek advice from the Planning Authority before lodging the submission.

Below is a photo of the site notice for the 36m application:

In the site notice the daa have confirmed that they interpreted the 32m passenger count as meaning one person equals one passenger. But for the 36m application they will now adhere to the IATA Standard. This is a clear admission that they have been skewing the passenger counts in order to breach the 32m limit. This 32m limit was imposed by An Bord Pleanála and the daa have effectively ignored it. The daa are trying to claim that the 32m limit imposed by An Bord Pleanala was related to surface access and road infrastructure. However, that is not the case.

Please refer to section 4.90 of the IAA's final decision on Summer 2025 coordination parameters: https://www.iaa.ie/docs/default-source/car-documents/1c-economic-regulation/s25-final-decision_final.pdf?sfvrsn=a88decf3_1.

> *"The IAA notes the following in respect of the 32mppa Conditions themselves. Certain of the assertions made by airlines (and in particular those of Ryanair and A4A) as to the genesis and primary purpose of the 32mppa Conditions are not correct.* ***It is apparent from the Terminal 2 planning material, in particular the report of the An Bord Pleanála inspector, that the 32mppa Conditions were instead specified as the direct result of a policy objective in a 2006 Dublin Airport Local Area Plan (LAP)****. That LAP contained a high-level objective that terminal passenger capacity beyond 30mppa should be provided by a third terminal on the western campus. The 32m annual limitation on terminals 1 and 2 was set on the basis that, if the capacity of those terminals were to exceed 32m, this might compromise the viability of this putative third terminal on the western campus (2mppa was added to the 30mppa figure for, effectively, contingency/flexibility purposes). It was, expressly,* ***not calculated based on any road traffic concern*** *(which concerns would, of course, not be effectively mitigated by an annual limitation in any case), or otherwise as a mitigation measure to address an environmental concern. We note that daa's submission that the 32mppa Conditions were each attached to the identified grants of planning permission following the carrying out of an environmental impact assessment completed pursuant to Council Directive 2011/92/EU, is also incorrect. The 2006 LAP upon which the 32mppa Conditions were actually based has since lapsed, and been replaced by a new LAP which provides, instead, for 40mppa on the eastern campus."*

So, it is very clear that the daa have deliberately used road infrastructure as a smoke screen to breach the 32m cap. This is again another breach of a condition from An Bord Pleanala and calls into question the integrity and purpose of the Board.

S146A request (ABP ref PL06F.220670)

In 2018, the Dublin Airport Authority made a request to An Bord Pleanála under S.146A to amend the wording of Condition no. 3 (**PL06F.220670)** to remove connecting passengers from the scope of the condition. The amended wording sought to include the words highlighted in bold as follows:

> 3. *The combined capacity of Terminal 2 as permitted together with Terminal 1 shall not exceed 32 million* ***origin-destination*** *passengers per annum unless otherwise authorised by a further grant of planning permission.*

The daa's letter can be viewed at:

https://planningapi.agileapplications.ie/api/application/document/FG/634827

In the letter from the daa, they elaborate on passenger types. This line is extremely relevant:

> ***"In line with international aviation convention such passengers are counted twice, once as an arriving passenger and secondly as a departing passenger*** *eg. 1000 transfer passengers are actually 500 people travelling through the airport."*

Therefore, the daa clearly acknowledged their interpretation that, in line with International Aviation Convention, transfer passengers are counted twice.

Clarification of Passengers Types

For much of its history Dublin Airport operated as primarily an origin-destination airport. This means that Dublin was either the departing or arriving destination for most passengers. At the time of the grant of the T2 planning permission, 99% of passengers were origin-destination passengers.

Connecting passengers are passengers who may travel through Dublin Airport, but Dublin is not their final destination.

The vast majority of connecting passengers are transfer passengers. They may arrive into Dublin on one aircraft and switch aircraft to complete the second leg of their journey towards their final destination. These passengers remain airside, and have no impact on transportation requirements at the airport. In line with international aviation convention such passengers are counted twice, once as an arriving passenger, and secondly as a departing passenger even though it is a single person travelling through the airport. For example, 1,000 transfer passengers is actually 500 people travelling through the airport.

A second type of connecting passenger is a transit passenger. A small number of aircraft stop at Dublin Airport for technical reasons including to refuel. Passengers on these flights are counted as transiting through the airport although they do not generally use the terminal buildings as they remain on the aircraft during the transit stop. It is much clearer that condition no. 3 doesn't apply to such passengers, however we include them for overall context.

Transfer and transit (collectively referred to as connecting passengers) do not impact the transportation network. An airport that facilitates connecting passengers may be referred to as a hub airport.

ABP's Direction of August 2018 stated:

> *"It is considered that the alteration sought would be material in planning terms, and cannot, therefore be considered under S.146A of the Act. The Board considered that the proposed alteration would enable greater throughput of overall passenger numbers through the airport. This greater level of activity would have material planning consequences (in terms of movement and access to the airport, airport capacity, and also in relation to planning policy relation to the airport) and would go beyond what was permitted in the permission granted."*

The decision on the S.146A application confirms that the limit of 32mmpa applies to **any** passenger type in the terminal buildings.

FS5/036/19

In September 2019, the daa made an application to Fingal County Council seeking a declaration under section 5 on whether development is or is not exempted development. The development consisted of the following:

> *"Three questions in relation to the use by passengers of the airport in excess of 32 million passengers per annum.*
>
> *(a) Is the use of the 'airport' in excess of 32 million passengers per annum (mppa) constitute 'development', if the combined capacity of Terminal 2 as permitted together with Terminal 1 does not exceed 32 mppa and if so, is it exempt development?*
>
> *(b) Is the use of the 'airport' by up to 3 million connecting passengers in excess of 32 million passengers per annum (mppa) constitute 'development' if those connecting passengers are facilitated by the separately permitted transfer facility and the combined capacity of Terminal 2 as permitted together with Terminal 1 does not exceed 32 mppa?*
>
> *(c) Currently a connecting passenger using Dublin Airport is double counted, as both an arriving and department passenger (for the purpose of aviation security measures). If a connecting passenger is counted singly for the purposes of planning, is this development, and if so, is it exempt development?"*

The decision by Fingal County Council was to refer it to An Bord Pleanala.

ABP-305458-19

The question to ABP was whether the 3 questions in FS5/036/19 in relation to the use of in excess of 32mppa is or is not development or is or is not exempted development

ABP's inspector stated in their report:

> *"Use of the "airport" by up to 3 million connecting passengers in excess of 32 million passengers per annum (mppa), if those connecting passengers are facilitated by the Pier 4 passenger transfer facility and the combined capacity of the facility together with Terminal 2 as permitted and Terminal 1 would exceed 32 mppa, would contravene condition no. 3 of PL06F.220670, and is therefore not exempted development."*

Therefore, the Board's inspector's view was that the use of the airport by 3 million connecting passengers was not exempted development. It therefore stands that the daa still needs to apply for planning permission to increase passenger numbers beyond 32mppa.

PPC 106276 & PPC 106336:

In a pre-planning document dated February 25th 2020 (reference Number: PPC 106276 & PPC 106336) between the daa, ANCA and Fingal County Council a discussion arose in relation to the interpretation of the 32mppa cap with regard to types of passengers:

- Discussion on the interpretation of the 32mppa passenger capacity cap with regard to types of passengers, in particular the transfer/ transit passengers.
- The P&SI Dept advises the applicant that, with reference to ABP decisions and known international, European and national methods of counting passengers at airports, the 32mppa passenger cap included in Condition 3 of F06A/1248 (PL 06F 220670) and Condition 2 of F06A/1843 (PL 06F 223469) is considered to be a cumulative, annual figure comprising all passengers using (traveling to, through and from) Dublin Airport.
- The P&SI Dept advises the applicant that as the 32mppa cap is considered to be all inclusive figure, it is not considered possible/ practical for planning assessment and subsequent enforcement purposes, to make any differentiation between different types of passengers.

End

Phillippa Joyce

3/3/2020

This is very clear advice from the Planning and Strategic Infrastructure Dept that the 32mppa is considered to be a cumulative, annual figure comprising **all** passengers using (traveling to, through and from) Dublin Airport. There is to be no differentiation between different types of passengers.

This new 36m planning application confirms that the daa deliberately misled the Planning Authorities and Judiciary on passenger numbers. They breached the cap in 2019, 2023 and again at the end of November 2024. They knew exactly what the passenger counting convention is and were told by the local Planning Authority. Therefore, they are knowingly carrying out Unlawful Development. The Relevant Action cannot be granted while the daa are knowingly carrying out Unlawful Development and the Board must refuse the Relevant Action on that basis or make the daa apply for retention.

F23A/0781:

Another worrying feature of the 36m planning notice is that:

> *"The proposed development would come into effect only in the event of, and subject to, a grant of planning permission for the change to permitted runway operations as proposed under ABP Ref. No. PL06F.314485 (F20A/0668)".*

This is the daa's attempt to blackmail and pressurise the Board into granting the Relevant Action. This is serious interference in the Planning process and the Board should not be intimidated by such actions.

The daa are giving the impression that the Relevant Action is needed to increase passenger numbers to 36m. I'm sure this will form part of the daa's submission on the draft decision. This is not the case and it's critical that the Board doesn't fall for this approach. In the 40m Infrastructure Application (F23A/0781), the daa submitted responses to a further information response from the Planning Authority.

In the EIAR submitted, Table 9-1 provides a breakdown of various assessments with and without the Relevant Action (NRRA) for different years:

Table 9-1: Assessment Years, Scenarios, Passengers and Flights

Assessment Year and Scenario	Predicted Annual Passengers (PAX) (millions per annum)	Aircraft Movements ('000s per annum)
Current State	32.8	234
2027 without Proposed Development without NRRA	32.0	228
2027 with Proposed Development without NRRA	33.2	233
2027 without Proposed Development with NRRA	32.0	240
2027 with Proposed Development with NRRA	35.6	258
2033 without Proposed Development with NRRA	32.0	240
2033 with Proposed Development with NRRA	40.0	279
2034 without Proposed Development without NRRA	32.0	228
2034 with Proposed Development without NRRA	40.0	269
2046 without Proposed Development without NRRA	32.0	228
2046 with Proposed Development without NRRA	40.0	268
2046 without Proposed Development with NRRA	32.0	240
2046 with Proposed Development with NRRA	40.0	279

By 2034 the daa can achieve 40mppa without the NRRA. Therefore, achieving 40mppa is not reliant on the Relevant Action being granted.

Even in 2027 the passenger numbers can increase to 33.2mppa without the Relevant Action. These figures are from the daa themselves and therefore they are

not being truthful when they say that the Relevant Action is needed to achieve either 36m or 40m passengers.

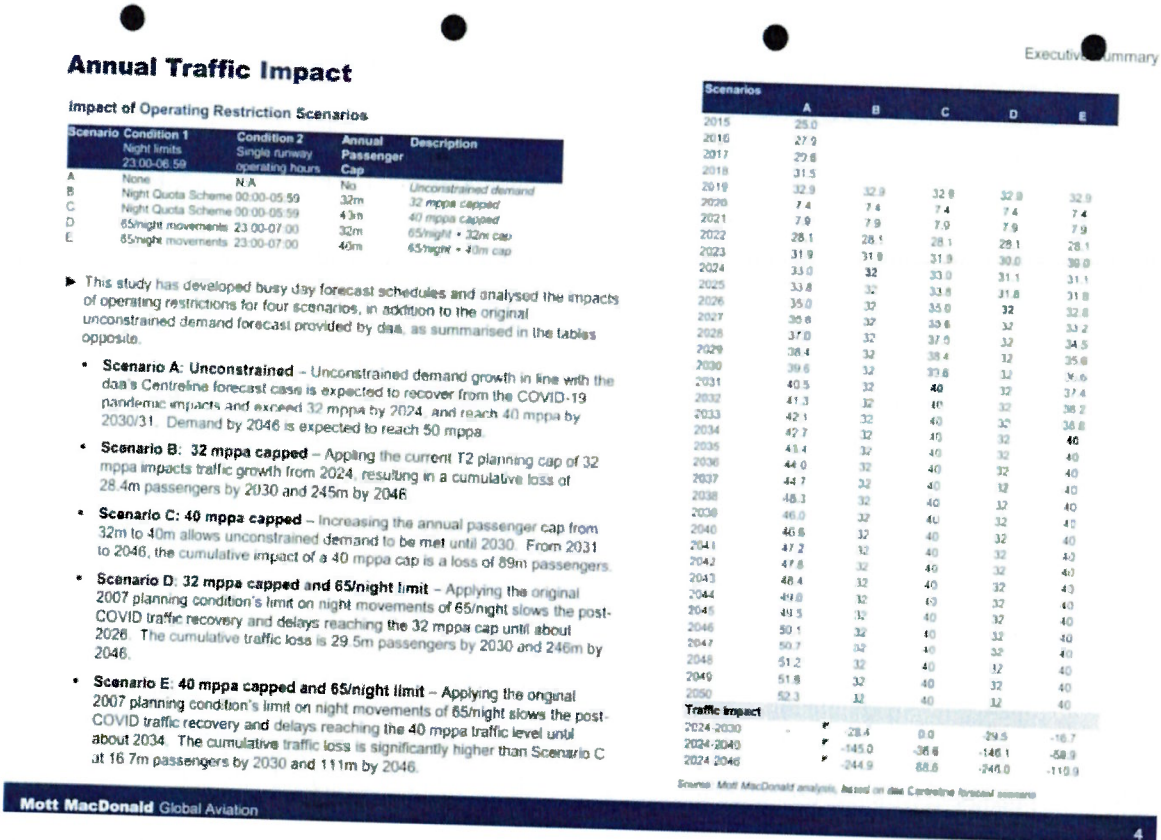
Section 9.1.23 under Table 9-1 is also very relevant:

> 9.1.23 The overall effect of the Proposed Development on the annual aircraft movements once 40mppa is reached (i.e. in the scenarios for 2031 and later) is an increase of 18% without the NRRA, or 16% with the NRRA. Considering the activity at night, there is no change due to the Proposed Development without the NRRA, and an increase of 14% with the NRRA.

There will be a 14% increase in activity at night with the NRRA. Section 9.1.23 states that there will be an increase of 18% without the NRRA as opposed to 16% with the NRRA.

Also included in the RFI material is a Mott MacDonald report titled "*Dublin Airport Operating Restrictions – Quantifications of Impacts on Future Traffic, Growth from 32m to 40million annual passenger – Fleet modernisation to 2046*", which can be found at page 1129 of https://planningapi.agileapplications.ie/api/application/document/FG/1067919.

On slide 4, Mott MacDonald compare various scenarios. Scenario E is noteworthy as it is the scenario without the Relevant Action being granted up to a cap of 40m passengers:



Annual Traffic Impact

Impact of Operating Restriction Scenarios

Scenario	Condition 1 Night limits 23:00-06:59	Condition 2 Single runway operating hours	Annual Passenger Cap	Description
A	None	N/A	No	*Unconstrained demand*
B	Night Quota Scheme 00:00-05:59		32m	*32 mppa capped*
C	Night Quota Scheme 00:00-05:59		43m	*40 mppa capped*
D	65/night movements 23:00-07:00		32m	*65/night + 32m cap*
E	65/night movements 23:00-07:00		40m	*65/night + 40m cap*

- This study has developed busy day forecast schedules and analysed the impacts of operating restrictions for four scenarios, in addition to the original unconstrained demand forecast provided by daa, as summarised in the tables opposite.
  - **Scenario A: Unconstrained** – Unconstrained demand growth in line with the daa's Centreline forecast case is expected to recover from the COVID-19 pandemic impacts and exceed 32 mppa by 2024, and reach 40 mppa by 2030/31. Demand by 2046 is expected to reach 50 mppa.
  - **Scenario B: 32 mppa capped** – Appling the current T2 planning cap of 32 mppa impacts traffic growth from 2024, resulting in a cumulative loss of 28.4m passengers by 2030 and 245m by 2046.
  - **Scenario C: 40 mppa capped** – Increasing the annual passenger cap from 32m to 40m allows unconstrained demand to be met until 2030. From 2031 to 2046, the cumulative impact of a 40 mppa cap is a loss of 89m passengers.
  - **Scenario D: 32 mppa capped and 65/night limit** – Applying the original 2007 planning condition's limit on night movements of 65/night slows the post-COVID traffic recovery and delays reaching the 32 mppa cap until about 2026. The cumulative traffic loss is 29.5m passengers by 2030 and 246m by 2046.
  - **Scenario E: 40 mppa capped and 65/night limit** – Applying the original 2007 planning condition's limit on night movements of 65/night slows the post-COVID traffic recovery and delays reaching the 40 mppa traffic level until about 2034. The cumulative traffic loss is significantly higher than Scenario C at 16.7m passengers by 2030 and 111m by 2046.

Executive Summary

Scenarios	A	B	C	D	E
2015	25.0				
2016	27.2				
2017	29.6				
2018	31.5				
2019	32.9	32.9	32.9	32.9	32.9
2020	7.4	7.4	7.4	7.4	7.4
2021	7.9	7.9	7.9	7.9	7.9
2022	28.1	28.1	28.1	28.1	28.1
2023	31.9	31.9	31.9	30.0	30.0
2024	33.0	32	33.0	31.1	31.1
2025	33.8	32	33.8	31.8	31.8
2026	35.0	32	35.0	32	32.8
2027	35.8	32	35.8	32	33.2
2028	37.0	32	37.0	32	34.5
2029	38.4	32	38.4	32	35.8
2030	39.6	32	39.6	32	36.6
2031	40.5	32	40	32	37.4
2032	41.3	32	40	32	38.2
2033	42.1	32	40	32	38.8
2034	42.7	32	40	32	40
2035	43.4	32	40	32	40
2036	44.0	32	40	32	40
2037	44.7	32	40	32	40
2038	46.3	32	40	32	40
2039	46.0	32	40	32	40
2040	46.6	32	40	32	40
2041	47.2	32	40	32	40
2042	47.8	32	40	32	40
2043	48.4	32	40	32	40
2044	49.0	32	40	32	40
2045	49.5	32	40	32	40
2046	50.1	32	40	32	40
2047	50.7	32	40	32	40
2048	51.2	32	40	32	40
2049	51.8	32	40	32	40
2050	52.3	32	40	32	40
Traffic impact					
2024-2030	-	-28.4	0.0	-29.5	-16.7
2024-2040	-	-145.0	-36.6	-146.1	-58.9
2024-2046	-	-244.9	88.6	-246.0	-110.9

Source: Mott MacDonald analysis, based on daa Centreline forecast scenario

Mott MacDonald Global Aviation 4

It is very clear that 40m passengers can be achieved using Scenario E by 2034. Also, it shows that 36.6m passengers can be achieved by 2030. The only impact the with or without Relevant Action has is the rate of growth of passenger numbers. Without the Relevant Action still achieves the goals of the National Aviation Policy.

This is very critical to highlight – Not granting the Relevant Action does not impinge on the goals of the National Aviation Policy.

40mppa will be achieved by 2034 with or without the Relevant Action. Therefore, if the Board does grant permission for the Relevant Action, it cannot be based on the aims of the National Aviation Policy. Also, the Board will need to justify why it is inflicting so much adverse health effects at night on residents for no gain in passenger numbers in 2034. The Board will have to justify the costs involved with the grant of the Relevant Action and how the health costs (750m euro annually) can be borne by the Irish taxpayer to subsidise the aviation industry. This is clearly not a Balanced Approach.

PFAS Contamination:

The known PFAS contamination at Dublin Airport has not been addressed by the Board. It is public knowledge that there's a sizeable PFAS contamination issue at Dublin Airport:

https://www.irishtimes.com/transport/2023/03/17/dublin-airport-operator-examining-potential-impact-of-forever-chemicals/

At a DAEWG meeting on the 15th of March 2023, the daa's Head of Environmental Sustainability advised members that:

> *"daa is examining the potential impact of PFAS at Dublin Airport and is engaging with the relevant environmental regulators to ensure best practice in managing this issue*".

https://www.dublinairport.com/docs/default-source/community-engagement/15-march-2023---daewg-meeting-minutes-approved.pdf

It has also been reported that Geminor shipped 150,000 tonnes of PFAS contaminated soil from Dublin Airport to Norway for processing:

https://www.wastetodaymagazine.com/news/geminor-pfas-dublin-soil-treatment/

This work by Geminor also has not formed part of any planning application or environmental assessment and has involved no public consultation. Therefore, this work is unauthorized development and needs immediate assessment and planning permission.

Because the PFAS contamination did not form part of a planning application, the cumulative effects of the PFAS works has not been taken into account in any planning applications. This is a serious omission and this unlawful development has had serious knock-on consequences to other developments at Dublin Airport. The impacts of the PFAS contamination has not been environmentally assessed for its impact on the environment and especially the SACs and SPAs that are hydrologically linked to Dublin Airport. The impact on human health have also not been addressed in any planning context.

The daa first became aware of the impacts of PFAS during the North Runway construction. The daa decided not to alert any relevant authority and continued construction with the Norh Runway. They knowingly continued to construct the runway and therefore these works should be categorised as Unauthorised. A full AA has never been carried out on the whole North Runway projects.

In April 2024 the daa uploaded 4 documents to their website at https://www.dublinairport.com/corporate/environmental-social-governance/sustainability

1) Daa Statement April 2024
2) PFAS FAQ April 2024
3) 2021 – 2023 Environmental Monitoring Non-Technical Summary
4) 2021-2023 Environmental Monitoring Report

In section 5.1 of the document '*2021 – 2023 Environmental Monitoring Non-Technical Summary*', it states:

- **Groundwater**:
  - The highest Sum of 20 PFAS concentrations in groundwater were detected at the site of a former firefighting training ground, where maximum concentrations of **4,111ng/l** were reported.
- **Surface Water**:
  - The highest PFOS concentration in surface water was detected in the Cuckoo Stream at 50.6ng/l (May 2023).
  - The highest PFOS concentration in airside surface water (**1,430ng/l** in March 2022) was recorded in a manhole to the north of the North Apron. The source of PFOS is indicated to be from the Former Fire Station at the North Apron.
- **Soil/Concrete**:
  - The highest concentrations of individual PFAS constituents in soils/concrete were **568µg/kg** in Apron 5H.

These are alarming levels of PFOS / PFAS.

Further documents were released by way of an appeal to the OCEI Commissioner: https://ocei.ie/en/ombudsman-decision/7db6a-daa-public-limited-company-and-fingal-county-council/

Upon release, the daa made the documents available on their website:

https://www.dublinairport.com/corporate/airport-development/north-runway/environment/soil-and-water-management

The two documents are different to the documents previously made available by the daa. These two new documents were undertaken by Fehily Timoney who were retained by RoadBridge to undertake a Risk Assessment of PFAS contamination of groundwater and surface water at the **former Fire Training facility at the Dublin Airport, North Runway development (APEC 5).** RoadBridge were the contractors responsible for the construction of the North Runway.

The report titled '*Groundwater and Surface Water Risk Assessment and Remediation Options Appraisal*', states in section 1.1 that:

"The detected concentrations of Total PFOS at the off-site surface water monitoring points sampled between January 2018 and July 2021 exceeded the:

- *0.65 ng/l (the annual Average Environmental Quality Standards (EQS) for Inland Surface Waters for Total PFOS set by S.I. No. 386 of 2015)."*

"A number of the groundwater monitoring locations during the period January 2018 and October 2018 exceeded the Total PFOS 0.07 µg/l threshold value (defined by the United States Environmental Protection Agency (USEPA) Drinking Water Advisories for PFOS and PFOA)."

The Board cannot grant permission to the Relevant Action when Unauthorised Development has taken place and where the PFAS contamination has not been screened in any of the three environmental assessments. The Board cannot claim that it does not know of PFAS as it has been raised in submissions. It is worth mentioning the **MetroLink** project which will involve works at the airport. TII are taking PFAS very seriously and is including it in their Cumulative Impact Assessment and In-Combination Assessment for NIS. While the daa are taking the opposite approach and failing to adequately address the issue.

The daa have known about PFAS contamination since as early as 2016 during construction of the North Runway and yet none of their Environmental Assessments since then even mention PFAS yet alone provide mitigation and remedial measures. The dangerous levels of PFAS / PFOS have been known for a long number of years now and the daa have only recently contacted the relevant authorities. The response from the daa was to initially remove and bury known contaminated soil from the North Runway site around attenuation tanks and continue with the North Runway development. This was a major mistake as the PFAS levels under the North Runway are at dangerous levels. PFAS contaminated soil has also been found at other sites at the airport and large amounts of contaminated soil from the Apron 5H development has been shipped to Norway for remediation.

The cumulative impacts of the contamination at the Apron 5H development site should be assessed in conjunction with this Relevant Action application. The whole airport site needs to be addressed for PFAS / PFOS contamination as a whole and not the piecemeal approach thus far. The need for Cumulative Assessment and In Combination Assessment are highlighted in the advice given to TII for MetroLink. TII are taking the PFAS situation very seriously and understand their obligations which are clearly lacking with the daa. TII acknowledge that their development will lead to PFAS release into the environment.

The daa have been aware since 2016 of the PFAS issue and decided to literally bury the evidence in order that the North Runway project would not be delayed. No consultation with State Authorities was carried out at the time. We note that no full AA was ever carried out on the North Runway. The daa knew of the PFAS contamination and yet still went ahead without addressing it and even got a time extension and defended High Court proceedings while still burying knowledge of this contamination. The North Runway should be classed as **Unauthorised Development**, and we ask that the Board make a ruling on this.

An Bord Pleanála are mandated to refuse planning permission based on the total lack of screening and assessment of PFAS / PFOS contamination and its impact on European sites.

Nighttime insulation grant

It is proposed in the draft decision to offer a grant of 20k euro for nighttime insulation of bedrooms. The Inspector has accepted the process that ANCA has conducted. The award of any grant should be costed by an organisation such as the Chartered Surveyors of Ireland or Engineers Ireland. 20k euro will not achieve much in 2025 and beyond. It is a derisory sum. Nighttime noise impacts more on health than daytime noise. Yet the daytime insulation scheme for those contained in the 63 LAeq16 contour offers full house insulation. The Board have not explained how 20k euro can achieve any satisfactory level of insulation to protect human health. In fact, the Board have not shown the competence with which they can arrive at that decision. The Board needs to engage proper Engineering and Surveying competence to make any determination on insulation.

Schedules:

In the daa's 2023 Annual Compliance report, https://www.fingal.ie/sites/default/files/2024-09/d00001-daa-xxx-xx-xxx-rp-v-xxx-0003-annual-compliance-report-section-19-2023-v1.0_0.pdf, Appendix 2 on page 54 lists the percentage of arrivals and departures per hour:

App 2 Arrivals and Departures by Hour

Hour	Arrivals	Departures
0	3.4%	0.4%
1	2.0%	0.2%
2	0.5%	0.4%
3	0.4%	0.1%
4	2.3%	0.3%
5	1.4%	1.2%
6	1.3%	7.9%
7	3.0%	9.2%
8	5.1%	5.9%
9	5.9%	5.2%
10	5.7%	5.2%
11	6.1%	6.0%
12	6.3%	6.0%
13	5.8%	6.7%
14	5.6%	5.7%
15	4.6%	6.1%
16	5.3%	5.7%
17	5.6%	6.1%
18	5.3%	6.0%
19	4.5%	5.2%
20	4.5%	4.3%
21	4.8%	3.4%
22	5.7%	2.0%
23	4.9%	0.8%
Total	100%	100%

The daa have always claimed that the 6-7am slot and 23-24pm slot are their busiest hours of operation. Assuming there's an even split of arrivals and departures for the entire day, the 6-7am slot has 9.2% (1.3 + 7.9) of total movements. However, when summing up the totals of arrivals and departures for every hour, it can be seen that the 6-7am slot is only the 14th busiest hour, and the 23-24pm slot is the 18th busiest hour. This makes a mockery of the daa's claims. Submissions on the schedules have been made repeatedly during this planning process by the St Margarets The Ward Residents Group and the Inspector has failed to date to understand how important the evidence in these schedules is and what can be learned from them that runs contrary to what the daa are saying. There has been no evidence provided in the draft decision that shows the Board understands the schedules or has taken the numerous submissions into account. The Board must interrogate the schedules, and will no doubt come to the same conclusion that the 6-7am timeslot is not the busiest.

Hour	Arrivals	Departures	Total
13	5.80%	6.70%	12.50%
12	6.30%	6.00%	12.30%
7	3.00%	9.20%	12.20%
11	6.10%	6.00%	12.10%
17	5.60%	6.10%	11.70%
14	5.60%	5.70%	11.30%
18	5.30%	6.00%	11.30%
9	5.90%	5.20%	11.10%
16	5.30%	5.70%	11.00%
8	5.10%	5.90%	11.00%
10	5.70%	5.20%	10.90%
15	4.60%	6.10%	10.70%
19	4.50%	5.20%	9.70%
6	1.30%	7.90%	9.20%
20	4.50%	4.30%	8.80%
21	4.80%	3.40%	8.20%
22	5.70%	2.00%	7.70%
23	4.90%	0.80%	5.70%
0	3.40%	0.40%	3.80%
5	1.40%	1.20%	2.60%
4	2.30%	0.30%	2.60%
1	2.00%	0.20%	2.20%
2	0.50%	0.40%	0.90%
3	0.40%	0.10%	0.50%
Total	100%	100%	

I reiterate that this data comes from a daa Compliance Report for 2023.

Independence:

The Director of ANCA, Ms Ethna Felten, is also Deputy CEO of Fingal County Council. This is a clear breach of EU598/2014 and the Aircraft Noise (Dublin Airport) Regulation Act 2019.

> *(13) The competent authority responsible for adopting noise-related operating restrictions should be* ***independent*** *of any organisation involved in the airport's operation, air transport or air navigation service provision, or representing the interests thereof and of the residents living in the vicinity of the airport. This should not be understood as requiring Member States to modify their administrative structures or decision-making procedures.*

Article 3:

> *2. The competent authorities shall be* ***independent*** *of any organisation which could be affected by noise-related action. That independence may be achieved through a functional separation.*

On the recent Dublin Airport Noise Action Plan, ANCA and their consultants worked in tandem with Fingal County Council. This does not seem fitting for an independent body.

The Board should clarify if ANCA's position is in accordance with EU598/2014 legislation.

Enforcement:

The flight paths issue is just one condition of planning that Fingal County Council's enforcement department are dealing with. Fingal has taken enforcement proceedings against the daa over breaching Condition 5 and not adhering to 65 nighttime flights. This matter is subject to High Court proceedings. The daa are not adhering to a condition of planning imposed by the Board and have sought a stay via the courts.

In section 12.4.8 of the Inspector's report, it states:

> *"I have no evidence before me to suggest the proposal for the RA is to address any unauthorised action. A response to the supplementary information was received by both ANCA and the PA and no issues relating to unauthorised development have been raised. Any non-compliance with the original NR permission and enforcement issues are a matter for the PA".*

The Board has an obligation to seek information from relevant authorities if required. It appears that the Inspector relied on a lack of material from the PA and ANCA. However, information should have been sought under the Board's powers.

I attach the Enforcement Notice, *PENF_0134_2023 S154 Enforcement Notice.pdf*, from Fingal County Council dated July 28th 2023. I also attach the record of Fingal's CEO, *PENF_0133_2023 S153.pdf*, which clearly states that the development is unauthorised:

- Taking account of the foregoing, it is therefore concluded that by virtue of the scheduled and actual operations reported, the frequency of night flights in Dublin Airport is not in conformity with Condition 5 of the North Runway permission an dis for that reason unauthorised development. The 2000 Act, including s.154(5)(a)(ii) provides that the planning authority can issue an Enforcement notice to require the daa, to proceed with a development in conformity with Condition 5;

- Unauthorised development is occurring and will continue to occur in non-conformity with Condition 5 and that unauthorised development is occurring at the Lands and development is not being carried out in conformity with Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429);

- The daa has not sought to remedy the said unauthorised development, there are no compelling reasons for not taking enforcement action, having regard to the nature of the unauthorised development at issue and the nature of Condition 5, including the reason/purpose of same;

- In circumstances where unauthorised dev elopment is occurring and will continue to occur at Dublin Airport, contrary to Condition 5 of the North Runway Permission (Planning Authority Reg. Ref No: F04A/1755 / ABP Ref. No: PL 06F.217429) comprising the continued and ongoing exceedance of the permitted average number of night-time (between 2300 hours and 0700 hours) aircraft movements at the airport – being a permitted average of 65 aircraft movements per night when measured over the 92-day modelling period;

I also attach an enforcement complaint form, *planning-enforcement-complaint-form-65-Flights-summer.pdf*, which lists out flights on June 25th/26th inside the 92-day Sumer period where 106 movements were recorded between 23:00-07:00.

These records provide proof to the Board that Unauthorised Development has been occurring in relation to Condition 5 (65 nighttime limit). The Board has a duty to recognise this Unauthorised Development and refuse the Relevant Action as it's now a case of retention permission.

The daa have also breached the 32m passenger cap conditioned by the Board as part of Terminal 2's planning. They breached it in 2019 and 2023 and have breached it again at the end of November 2024. The passenger numbers can be viewed on daa's own corporate website at https://www.daa.ie/wp-content/uploads/2024/12/daa-Monthly-Statistics-November-2024.pdf. It shows that Dublin Airport has handled 32,250,020 passengers at the end of November. This webpage is accessed via the daa's 'investor relations' webpage. These are the passenger numbers they show off to their investors. This 32m passenger cap was another planning condition imposed by the Board when granting planning permission for Terminal 2. This once again shows the lack of respect for the Board by the daa and they believe they are above the planning laws of this country.

Dublin Airport - November 2024 Statistics

Region	Nov 2024	Nov 2023	% Change	YTD 2024	YTD 2023	% Change
Domestic	12,195	12,678	-4%	162,943	142,996	14%
Great Britain	786,037	769,810	2%	8,981,214	8,712,705	3%
Rest of Europe	1,229,461	1,191,001	3%	18,129,892	17,427,641	4%
Transatlantic	240,924	244,484	-1%	3,904,885	3,651,362	7%
Other International	91,358	80,508	13%	1,062,488	932,492	14%
Transit	915	1,235	-26%	8,598	248,957	-97%
Total Passengers	**2,360,890**	**2,299,716**	3%	**32,250,020**	**31,116,153**	4%
Commercial ATM's	16,597	16,709	-1%	219,717	215,841	2%

I attach correspondence, *ENF_24-263_Dublin_Airport_32m_cap.pdf*, from the enforcement section of Fingal County Council where they state that a Warning Letter pursuant to Section 152 of the Planning and Development Act 2000, as amended, was issued to the daa on December 17th 2024.

The daa breached the cap in 2019 (32.9m), 2023 (33.522m) and now again at the end of November 2024 (32.25m). The final figure will be above 34.6m passenger. This is the repeated ignoring of a planning condition imposed by An Bord Pleanála and is therefore Unauthorised Development. The Board must acknowledge this breach and have the daa apply for retention.

Climate:

Another major issue central to the nighttime flights application and the expansion of aviation is the significant increase in Green House Gases (GHG) emissions. GHG emissions were never assessed for significance in the original planning for the North Runway and therefore no Baseline for emissions was established. Therefore, all emissions from the proposed Relevant Action need to be accounted for and these are '*major adverse*' when accounted for based on the IEMA Guidelines. It is highly significant that the SEAI recently published a report, Energy in Ireland 2024 (https://www.seai.ie/sites/default/files/publications/energy-in-ireland-2024.pdf), estimating that "*Ireland's emissions from International aviation amounted to 3.4 MtCO2eq, equivalent to approximately 11% of national energy-related emissions.*"

Table 7.1: Energy-related CO_2eq by sector (share)

GHG [$MtCO_2eq$]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Electricity gene ration	11.70	1 153	12. B	12.86	12.05	107 0	94 5	8 86	10.36	10 .14	8.03
Tran spo rt (excl.int. aviation)	10.92	11.20	11.69	12.21	12.05	12. 22	12.22	1 0.29	1 097	11.64	11 .68
I ndustry	3.39	3 .61	359	3.71	3.83	4.05	3.97	4.02	4.04	3.81	3 .62
R esidentia l	7.07	6.27	6.71	7.00	6.51	7.00	6.73	7.34	6.87	5.75	5.35
Services	1.50	1.41	1.54	145	1 .39	1.51	1.50	1.31	1 .41	1.39	1.35
Agriculture	0.59	0.53	0.51	0.54	0.55	0.59	0.61	0.62	0.6 2	0.85	0 76
Fisher ies	0. 08	0 .07	0.07	0.06	0.07	0.08	007	0.06	0.06	0.05	0.06
Other	0.48	0.44	0.53	0.4 2	0 .47	0.52	0.46	0.48	04 7	0.47	0.42
Total (excl. int. aviation)	**35.72**	**35.06**	**36.77**	**38.24**	**36.92**	**36.67**	**35.02**	**32.99**	**34.79**	**34.11**	**31.27**
International aviatio n	2.02	2.24	2.54	2.60	3.06	3.31	3.34	1.19	1.32	3.04	3.44
Total (incl. int. aviation)	**37.74**	**37.30**	**39.30**	**40.84**	**39.98**	**39.98**	**38.36**	**34.17**	**36.12**	**37.15**	**34. 71**

It also showed that Jet kerosene contributed 22.8% of energy related CO2 emission in transport:

Table 7.3: Quantities and shares of energy-related CO_2eq emissions in transport (share)

GHG [MtCO_2eq]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Diesel / gasoil	7.34	7.80	8.46	9.16	9.29	9.69	9.82	8.50	9.07	9.48	9.38
Jet kerosene	2.03	2.25	2.55	2.61	3.07	3.32	3.36	1.20	1.34	3.06	3.46
Gasoline	3.54	3.35	3.17	2.96	2.67	2.43	2.30	1.70	1.81	2.06	2.19
Electricity	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.05	0.07	0.08
Biodiesel	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.05
Natural gas	0.01	0.01	0.01	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
LPG	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Bioethanol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fuel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**12.96**	**13.46**	**14.24**	**14.83**	**15.14**	**15.55**	**15.59**	**11.51**	**12.35**	**14.76**	**15.20**

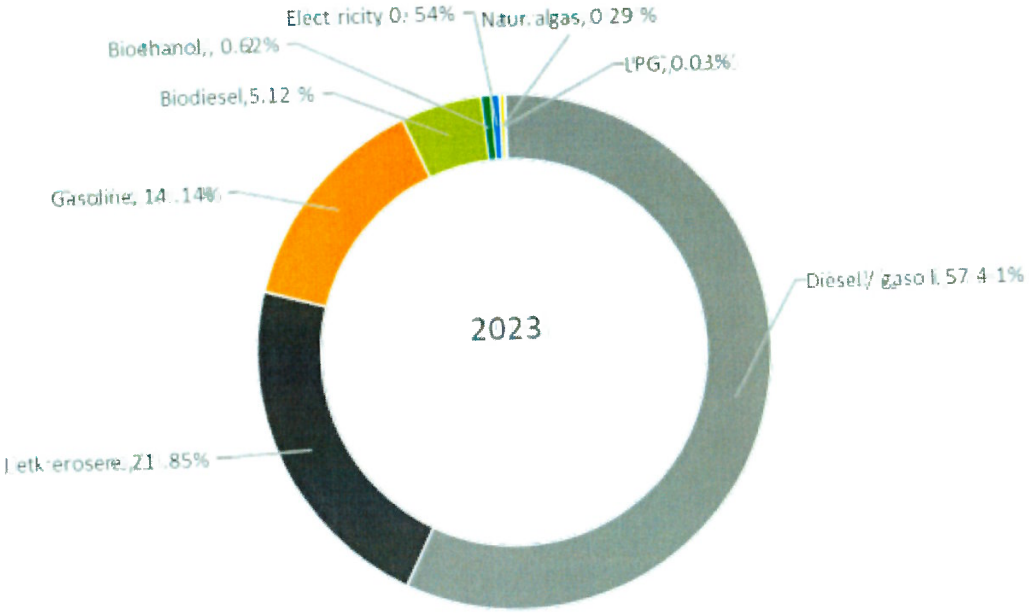
Jet Kerosene use in 2023 surpassed the previous yearly high in 2019:

Table 5.4: Final energy in transport sector by energy types (share)

Energy [TWh]	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Diesel / gasoil	27.50	29.25	31.72	34.32	34.80	36.31	36.80	31.83	33.98	35.50	35.10
Jet kerosene	7.85	8.70	9.84	10.10	11.88	12.83	12.98	4.63	5.18	11.84	13.36
Gasoline	13.93	13.18	12.50	11.66	10.52	9.59	9.08	6.73	7.13	8.12	8.65
Biodiesel	0.86	1.04	1.14	1.00	1.52	1.48	1.90	1.82	1.87	2.37	3.13
Bioethanol	0.33	0.31	0.35	0.38	0.34	0.32	0.30	0.23	0.24	0.27	0.38
Electricity	0.04	0.04	0.04	0.05	0.05	0.07	0.09	0.10	0.15	0.22	0.33
Natural gas	0.04	0.03	0.05	0.25	0.24	0.26	0.20	0.18	0.19	0.19	0.18
LPG	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02
Fuel oil	0	0	0	0	0	0	0	0	0	0	0
Total	**50.57**	**52.58**	**55.67**	**57.79**	**59.38**	**60.87**	**61.36**	**45.53**	**48.74**	**58.53**	**61.14**

Jet Kerosene accounted for 21.85% of all transport energy use:

Figu re5.7: Sha re of energy types in transport final energy



It's imperative that these highly significant GHG emissions from aviation are kept in line with Ireland's obligation under the Paris Agreement.

Significance:

Significance of effects was never established in the original planning application. As a result, the daa has no baseline on which to determine significance with their proposal. It is not just the difference between the Permitted and Proposed scenarios that determines those significantly affected as the Permitted scenario was never assessed for significance. It also needs to be pointed out that the Permitted scenario is not equal to the baseline situation in 2007 or the consented scenario with straight out flight paths. It is also of note that the change to the new flight paths, acknowledged by the daa, was not stated on the Public Notice for the Relevant Action or on the Public Notice from An Bord Pleanála. This is a grave error and totally misleads the public who were not anticipating divergent flight paths.

The Board should be made aware of the RFI responses from the daa's planning consultants, Coakley O'Neill, for the Infrastructure Application, F23A/0781. The planning authority made the following request in question number 6:

> *"The applicant is invited to provide analysis with narrative explaining the variation over time, of previously modelled aircraft noise contours far Dublin Airport. The analysts should be accompanied by an overlay graphical representation of noise modelling prepared and presented as contours for the currently proposed development shown with each of the following previously presented contours: 1) the North Runway application (December 2005 515),*

2) the consented Worth Runway (EIS Addendum 9th August 2007) 3) the modelling agreed for operation of the noise mitigation schemes under that permission (2016) 4) the Airport Noise Zones in the Fingal Development Plan 2023. The methodological differences between the various contours and the reasons why they are not directly comparable should be noted."

The response can be accessed in this document: https://planningapi.agileapplications.ie/api/application/document/FG/1067909. Coakley O'Neill provide a timeline of events, some of which are:

- *"North Runway Application (December 2004 EIS):*
  - *The flight routes assumed that the North Runway tracks would replicate those on the South Runway. These assumed aircraft turned after a straight segment of around 5 nm from the end of the runway*
- *Modelling agreed for operation of the noise mitigation schemes (2016):*
  - *The flight routes assumed that the north runway tracks would replicate those on the south runway. These assumed that 25% of aircraft turned after a straight segment of around 5 nm from the end of the runway, with the remaining 75% turning earlier, around 2 nm from the end of the runway. This was based on an analysis of a sample of radar flight tracks.*
- *IA EIAR (December 2023):*
  - *The flight routes were based cm an analysis of actual radar tracks. For the South Runway these were similar to previous assumptions. For the North Runway this meant an initial 30 degree right turn shortly after the end of the runway After this initial turn the routes are similar to previous assumptions.*

This response is written in the context of the Board Inspector's findings in her assessment of the North Runway Relevant Action (NRRA), ABP Ref. No. ABP-314465-22 (F20A/0668), which stated that:

> *"the Board will note that the flight patterns submitted in the applicant's supplementary information and included far the purpose of the proposed scenario of the EIAR, differ to those submitted in the original EIS for the NR application. The Board will note that the flight patterns submitted to the planning authority for the original Relevant Action also differed from those submitted with the original EIS for the NR application The main difference between the revised EIAR and the amended supplementary EIAR is the divergence north from the NR, earlier than previously indicated in the revised EIAR permitted by the planning authority""*

This is irrevocable proof that the daa have come clean and are agreeing with the Inspector that the flight paths have changed. This is in complete contrast to what the daa has been saying to the Planning Authority, ANCA, Irish people and the Oireachtas. Here are examples from the Oireachtas Transport Committee:

<u>January 18th 2023:</u>

https://www.oireachtas.ie/en/debates/debate/joint_committee_on_transport_and_communications/2023-01-18/3/

Deputy Darren O'Rourke

There was an application in 2007 Ms Gubbins is referencing 2016. I am aware Fingal County Council has issued an enforcement notice. I wonder about the basis on which the DAA is operating now and the basis on which it will operate on 23 February in the context of planning and the regulator. Will the applications have been adequately through those processes or does the DAA need to seek retention? Are other enforcement notices expected? Is the DAA of the opinion that from 23 February it will be entirely sound to operate those flight paths with regard to the regulators and the Aircraft Noise Competent Authority, ANCA, and all the various parameters that one must live within?

Ms Catherine Gubbins

There are two separate issues at play here. The Deputy referred to the deviation in the flight path. That specific issue will, hopefully, be resolved on 23 February, as we have discussed. The actual flight paths, whether they are the deviated or the original, are not a factor of our planning permission. The Deputy referred to the 2007 application. The north runway was constructed under a planning permission that was granted in 2007. The Deputy is absolutely right that we are currently engaged in a process, which the noise regulator ANCA, has made a decision on. This has been appealed to An Bord Pleanála. We are actually in the process of engagement around separate conditions to do with that 2007 planning permission, which to our mind is a completely separate process to the flight path deviation issue that we had previously discussed. As of 23 February, we are very hopeful that the new flight path will be in place, and hopefully that issue will be resolved. We are in the middle of a statutory process, which absolutely needs to run its course over the next few months.

Deputy Darren O' Rourke

Picking up from that point, I presume that in its assessment the DAA has been advised on this. The community might reasonably ask if the 2007 planning permission is being contested but the runway is being operated at the same time, whether the DAA is of the opinion that it is operating the north runway on a sound basis, despite the fact there are ongoing legals in relation to that planning?

The video for this meeting can be accessed at Joint Committee on Transport and Communications debate - Wednesday, 18 Jan 2023. At 1:23:10 into the video the Acting Chairman Senator Gerry Horkan asks Ms Catherine Gubbins the following question:

Acting Chairman (Senator Gerry Horkan)

For my own benefit can I just confirm that the DAA is operating the north runway on the basis of the existing planning permission as opposed to what the DAA would like the planning permission to be into the future? Yes

Ms Gubbins replied 'Yes' that the daa were operating the North Runway on the basis of the existing planning permission.

November 22nd 2023:

https://www.oireachtas.ie/en/debates/debate/joint_committee_on_transport_and_communications/2023-11-22/2/

Mr. Kenny Jacobs

Flight paths are complicated and they take a long time to work through. When flights commenced on the north runway from August to February, there was a slight deviation for some flights. A small number of aircraft were marginally overflying parts of a community that were not consulted with. That has been corrected from February, which is the most important thing. That was a mistake that we had made. We apologised for it. The flight paths that operate now are fully compliant. They are the flight paths that were intended and are over the communities that were consulted with.

Deputy Steven Matthews

I am glad to hear that the DAA met with representatives of the Kilcoskan school recently. I have been contacted by residents and parents of children who attend the school as they really have difficulty with some of the noise issues. From February 2023, the flight paths relating to the north runway are as proposed in the original planning application from 2007 and the amended one.

Mr. Kenny Jacobs

Exactly, yes.

Example from the daa's own website:

https://www.dublinairport.com/latest-news/2023/03/15/daa-rejects-any-claims-that-it-is-in-breach-of-planning-permission-granted-in-respect-of-the-north-runway

Example from PrimeTime:

https://www.youtube.com/watch?v=jV78GFDwA6Y (3:30 into the audio)

This is proof that the daa misled the Oireachtas and Irish people.

Health costs:

Another serious concern with the daa's submission is that the health costs of nighttime noise have not been assessed. The public have gone to great lengths to point out the strong recommendations of the WHO and the submissions from the HSE, yet the daa and ANCA fail to address health. Neither the daa nor ANCA assess the health costs and other negative impacts of increased aviation activity. Aviation cannot be subsidised, and the impact and cost picked up by the public and Health system. It has been estimated that the health costs associated to just the number of people Highly Annoyed and Highly Sleep Disturbed amounted to **€750million in 2023** alone based on the methodology used in a report commissioned by the Belgian Superior Health Council:

https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/20240506_hgr-9741_vliegtuiglawaai_en_andere_emissies_vweb.pdf.

https://wakeupkraainem.be/wp-content/uploads/2023/06/ENVISA_Health-Economic-Impact-Brussels-Airport_March-2023.pdf,

The research used €132,000 as the cost of a Disability Adjusted Life Year (DALY). For Dublin Airport the number of DALYs attributed to High Annoyance was 1,428 and for Sleep Disturbance 2,279. The combined estimate of High Annoyance and High Sleep Disturbance amounts to €489m. An estimate for CVD adds another €300 amounting to €789m in total for just 2023 alone. These figures have never been addressed by ANCA, the Planning Authoriity or the Inspector.

Project Ireland 2024:

Another major flaw in the daa's proposal is that it is contrary to the objectives of Project Ireland 2024 and Balanced Regional Development. 90% of international aviation into Ireland is via Dublin Airport. The other airports must fight for the remaining 10%. As a result, the economic benefits of Dublin Airport are totally lob sided to Fingal, Dublin, and the Leinster region. How can Fingal County council be independent in its decision making when the economic benefits of Dublin Airport are felt strongest in Fingal?

Appropriate Assessment:

The AA assessment by the applicant and the AA assessment from ANCA fail to assess the impacts on the Red Kite, which is an Annex I species.

A full NIS was never carried out on the whole North Runway project. This is classic project-splitting and piecemeal development.

The most recent Bird Survey was carried out in 2018 which is out of date and the Board cannot make a determination on AA based on such out-of-date surveys. This goes against the advice of the CIEEM.

The Board's ecologist never read any of the appeals or other submissions made on AA.

The AECOM report misled the authorities on the noise levels at the various SPAs and SACs. The noise levels are far higher than reported and can be seen in the daa's Noise snf Flight Track Monitoring Reports: https://www.dublinairport.com/corporate/environmental-social-governance/noise/noise-management/airport-noise-plans-and-reports. Regular exceedance of 70dB LAmax is achieved at the SPAs and SACs which does impact on birds according to the scientific literature.

No bird surveys taken under the Norh Runway flight path or at night.

No Cumulative or In-Combination assessments were carried out with other projects which is in breach of Article 6(3) of the Habitats Directive.

ANCA's AA only dealt with noise in isolation, and it too is defective with regard to noise levels.

The AA screening report by the Planning Authority is dated August 2022 before the North Runway opened and therefore insufficient, and no other projects were assessed for in-combination effects.

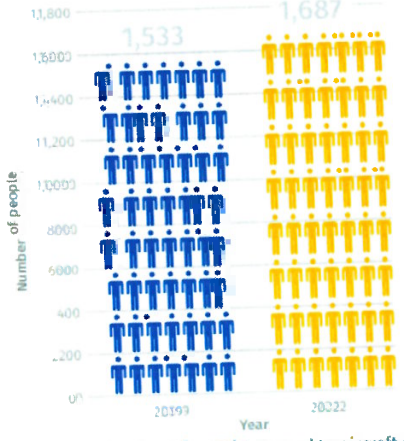
Noise Abatement Objective (NAO):

ANCA reviewed the mitigation effectiveness at Dublin Airport for 2022 and 2023 and reported that Dublin Airport failed the Noise Abatement Objective (NAO) in both years. This was mainly due to more of the population exposed to >55dB Lnight in close proximity to Dublin Airport.

https://www.fingal.ie/sites/default/files/2023-08/Noise%20mitigation%20effectiveness%20review%20report%20for%202022.pdf

The night-time NAO priority indicator

The fourth indicator of the NAO has regard to the total number of people exposed above the NAO priority level of 55dB L_{night}



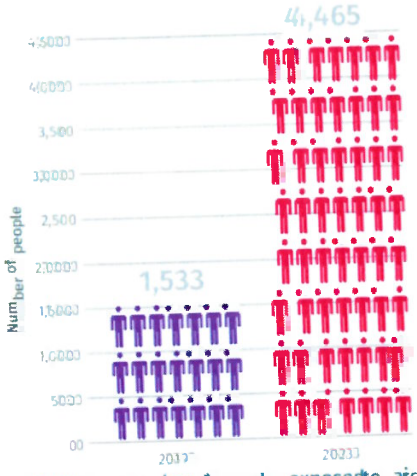
These overall figures must also be examined at the level of individual noise bands to facilitate the identification of targeted measures where necessary.

Figure 12 – Number of people exposed to aircraft noise above 55dB L_{night}

https://www.fingal.ie/sites/default/files/2024-08/noise-mitigation-effectiveness-review-report-for-2023.pdf

Compared to the situation in 2019:

- The number of people exposed to aircraft noise above 55 dB L_{night} shall be reduced.



When compared to the situation in 2019, the number of people exposed to the NAO priority limit of 55 dB L_{night} was higher in 2023 by 2,932 (191%)

Figure 14 – Number of people exposed to aircraft noise above 55db L_{night}

The number of people exposed to >55dB Lnight was 1687 in 2022 and escalated to 4465 in 2023. Note ANCA took no measures as a result of these breaches. ANCA cannot be relied upon to protect the health of residents of Fingal. This is very

disturbing and calls into question ANCA's role as an Independent Regulator. Its own reports clearly shows that people's lives are being put at risk. What is very worrying about ANCA is that they have never engaged medical experts or professionals to understand the effects of aircraft noise on Human Health. EU598/2014 clearly states that health should be taken into account, but ANCA have refused to engage.

Notwithstanding these breaches of the NAO in 2022 and 2023, 2019 is a flawed year to use as the NAO baseline year. In 2019, Dublin Airport facilitated 32.9m passengers, breaching the planning condition of 32m imposed by An Bord Pleanála. The Baseline year for the NAO should be in line with the EU Action Plan '*Towards a Zero Pollution for Air, Land and Soil*', which refers to 2017.

It is also worth highlighting from the 2023 report the population exposed to noise compared to the EIAR Supplement.

EIAR Supplement:

- 53,854 people Highly Annoyed
- 23,844 people Highly Sleep Disturbed

2023 Noise Mitigation Effectiveness Report:

- 71,388 people were Highly Annoyed
- 32,562 people were Highly Sleep Disturbed

This clearly shows that the Supplementary EIAR is vastly underreporting and underpredicting the real noise levels. The 2023 noise figures are real noise data and not modelled. The Relevant Action has fictional scenarios with a 32m passenger limit. This is pure fabrication, and the Board need to take on board the real 2023 noise levels when determining the impacts of noise.

The HA and HSD numbers on their own are not that meaningful. The formulae to derive the HA and HSD figures are based on Exposure Response Functions that are described in the WHO 2018 Guidelines.

Table 30. The association between exposure to aircraft noise (L_{den}) and annoyance (%HA)

L_{den} (dB)	%HA
40	1.2
45	9.4
50	17.9
55	26.7
60	36.0
65	45.5
70	55.5

At 40dB Lden, 1.2% of the exposed population are highly annoyed, rising to 55.5% of the population exposed at 70dB Lden. The % increases as the noise increases.

Table 32. The association between exposure to aircraft noise (L_{night}) and sleep disturbance (%HSD)

L_{night}	%HSD	95% CI
40	1 1.3	4.72–1 7.8
45	1 5 0	6.95– 23.08
50	19.7	987–29.60
55	2 5.5	13.57–37.4 1
60	323	18.1 5–46.36
65	40.0	23 .65–5605

At 40dB Lnight, 11.3% of the exposed population are highly sleep disturbed, rising to 40% of the population exposed at 65dB Lnight. Again the % increases as the noise increases.

The calculation of HA and HSD can be simplified as the sum of the population in each noise band multiplied by the %HA or %HSD for each band.

The ANCA 2023 Noise Mitigation Effectiveness Report breaks down the number of people in each band for both HA and HSD:

HA:

	45-49 dB	50-54 dB	55-59d B	6064 dB	65 69 dB	70-74dB	>75 dB
2019	74,905	29814	8,546	2,328	126	15	4
2023	3 7,959	20,9 83	8, 753	3,532	1 48	13	0

HSD:

	40-44 dB	45-49 dB	50-54dB	5 -59 dB	60-64 dB	65-69 dB	>70 dB
2019	36,339	76 22	2, 665	380	34	5	0
2023	20,101	7,252	4,0 03	1,14 7	5 5	4	0

It's very evident that from 2019 to 2023 the number of people HA reduced in the bands 45-49dB and 50-54dB but increased in all other bands.

It's also very evident that the number of people HSD reduced in the bands 40-44dB and 45-49dB but increased in other bands.

What this shows is that the numbers in the bands with the lowest noise levels have reduced but the numbers in the bands with the highest noise levels have increased.

ANCA is fixated on reducing the numbers of HA and HSD and is not concerned about the makeup of these numbers. ANCA is quite content that the overall numbers are reducing but has no interest that the number of people exposed to the highest levels of noise are increasing.

This is clear evidence that the overall HA and HSD numbers mask the effect that higher noise levels are impacting a larger cohort of people.

A worthwhile exercise is to compute the HA and HSD number based on the Environmental Noise Directive (END) reporting limits of 50dB Lnight and 55dB Lden.

Using the tables in the ANCA 2023 report which were shown above and summing the numbers in the bands from 50-54dB Lnight upwards and from 55-59dB Lden upwards:

Year	HA	HSD
2019	11,019	3,084
2023	12,446	5,209

These values paint a very different picture and show that the number of HA and HSD rose between 2019 and 2023 when you start counting at the END limit thresholds. The numbers being relied upon by ANCA in their NAO are skewed by the numbers in the lowest noise bands.

It's also worth highlighting that these lowest noise bands are where the largest populations in Dublin reside. A marginal effect at the lowest noise bands has a significant effect on the HA and HSD numbers.

From data extracted from the ANCA Reporting Templates for the Relevant Action and Reporting Template for 2023, a comparison can be made of the population in the Lden and Lnight contours for 2019 and 2023:

dB Lden	2019	2023
>=45	754135	419796
>=50	174146	132890
>=55	34097	37037
>=60	6279	9102
>=65	285	320
>=70	31	22
>=75	6	0

dB Lnight	2019	2023
>=40	344912	220460
>=45	59307	65227
>=50	13838	22417
>=55	1533	4339
>=60	110	159
>=65	13	8
>=70	0	0

From the Lden figures, 579,989 people resided in the 45-49dB Lden band in 2019 which is 77% of the total population exposed to greater than 45dB Lden.

From the Lnight figures, 285,605 people resided in the 40-44dB Lden band in 2019 which is 83% of the total population exposed to greater than 40dB Lnight.

Therefore, it's evidently clear that the quietest bands have a disproportionate number of people residing in the bands and therefore have a huge effect on the HA and HSD numbers if the noise contours change ever so slightly at the lowest bands.

From the tables above, based on the END reporting limits, 37,037 were exposed to >55dB Lden in 2023 compared to 34,097 in 2019 and 22,417 were exposed to >50dB Lnight in 2023 compared to 13,838 in 2019.

This is the reason that the HA and HSD figures above based on the END reporting limits are higher in 2023 than in 2019. The number of people exposed to the higher noise levels have been increasing.

Health

Attached to this submission are a list of scientific papers that provide expert advice on the impacts of Aviation Noise on health. Some of these papers are new and are after the WHO 2018 Guidelines were published. I encourage the Board to get the relevant expertise who can read and understand this literature and help make informed decisions. The Board must consult with medical experts if it doesn't have the necessary expertise to make an informed determination by taking this advice.

- *Transportation_Noise_Pollution_and_Cardiovascular_Health.pdf*
- *advisory-report-the-influence-of-night-time-noise-on-sleep-and-health.pdf*
- *Basner_aircraft_noise_exposure.pdf*
- *Basner_effects_on_sleep.pdf*
- *Basner_Environmental_Noise_and_Effects_on_Sleep.pdf*
- *Daytime_vs_Nighttime_effects_of_aircraft_noise.pdf*
- *20240624-ppt-Hahad.pdf*
- *enhealth-guidance-the-health-effects-of-environmental-noise.pdf*
- *Noise_causes_cardiovascular_disease.pdf*
- *Tech 11 2010 Good practice guide on noise.pdf*

I also attach the *Dublin_Airport_Noise_Medical_Report.pdf* from Professor Thomas Münzel, one of the world's leading experts on aviation noise and its effects on Human Health. Some of the key conclusions on his assessment of the Relevant Action are:

- *In addition to the fact that noise is now recognized as a cardiovascular risk factor, all possible measures must be taken to protect people who live near airports from the health consequences of noise.*
- *Based on the current study situation, it should be assumed that average outside noise levels caused by aircraft noise over a period of 24 hours, beginning around 40 dB (A), are associated with harmful effects. From this area on, increased noise pollution is to be expected, which is considered an effect modifier when communicating negative health consequences. Since night-time aircraft noise in particular has negative effects on health, stricter*

measures must be used in order to comply with the WHO recommendation (indoor noise level of less than 25 dB Lnight)

- *The noise study conducted on dwellings in close proximity to Dublin Airport shows that mitigation through insulation cannot reduce the noise to safe levels.*
- *Due to the new data on the negative health effects related to night-time aircraft noise, the number of night flights must remain limited and, in our opinion, cannot be increased any further.*
- *Due to the fact that night aircraft noise in particular is harmful to health, air traffic should, if unavoidable, be shifted more to the daytime.*
- *The legally defined night's sleep from 11:00 p.m. to 7:00 a.m. should be aimed for.*

It is unclear from the Inspector's report whether the Inspector has read this report and understands it. There is no evidence available in the Inspector's report to show that the Board received expert advice and obtained the expertise to thoroughly understand the evidence provided. Had an Oral Hearing been granted, the Inspector would have had the opportunity to hear first hands from one of the leading medical experts in transportation noise. It is clear from the Inspector's report that the Board have not provided proof of their expertise to understand the content of such a report. **The Board should now take this opportunity to obtain expertise from the appropriate experts to ensure they can come to a qualified determination.**

Noise Monitoring and Modelling:

It is very apparent that the Relevant Action leads to a serious deterioration in the noise situation for Fingal residents. Serious questions need to be asked about the daa's noise modelling. Only one portable noise monitor was used to calibrate the North Runway. They have used fixed monitors from the South Runway to attempt to calibrate divergent flight paths on the North Runway. The North Runway has been in operation for over 2 years now. The daa and ANCA have had plenty of time to collect reliable real measurements from under the North Runway.

Due to the lack of monitoring the local community have had to go to great lengths and cost to carry out their own independent monitoring. Monitoring was performed at 3 locations under the North Runway flight paths for the entire 92-day summer period in 2023 and 2024. The results of this monitoring show that the modelling presented in the EIAR Supplement is unreliable and very inaccurate for the North Runway, leading to variations of 2dB. This modelling cannot be trusted. The community engaged independent Acoustic experts to provide an expert opinion on the modelling and that evidence is attached to this submission.

Further comments:

The proposed insulation scheme and mitigation measures proposed by the daa are insufficient to ensure that all significant effects are avoided, prevented, or reduced. The effects of aircraft noise on the cardiovascular system are indisputable and it can exacerbate preexisting cardiovascular disease. The WHO 2018 Guidelines evaluated the scientific literature up to 2015. Since then, there is increasing evidence supporting the adverse effects of aircraft noise, nighttime noise in particular, on health. The vulnerable in society are more susceptible. Aircraft noise can have long term and permanent effects on children's cognitive ability, mental and physical well-being. Sleep is disrupted by aircraft noise. The pattern and frequency of aircraft noise renders it more likely to cause sleep disturbance. With the proposal, communities impacted by the North Runway are somehow expected to get their full night's sleep in a restricted 6-hour timeframe (24:00-06:00). This is extremely unhealthy when sleep is disturbed and limited. This additional use of the North Runway at night also increases the significant adverse effects of the North Runway, contrary to the planning permission conditioned by ABP in 2007. Why increase the number of people significantly adversely affected and inflict serious noise and health problems on a whole new cohort of the population when there are alternatives available?

The Board's draft decision has recommended the approval of the NQS proposal from the daa along with a movement limit of 13000 movements. The Quota Count itself should also be adjusted far below 16260 in line with counterparts in the UK.

The biggest impact on my family is the result of Westerly arrivals into the North Runway. The aircraft are so low and noisy, and it impacts severely on the use of our house. The external amenity of our house is obliterated during these Westerly arrivals. Thankfully we are only exposed to these westerly arrivals on the North Runway 30% of the time due to the Wind direction. However, the daa and ANCA average out these extremes of noise into annual averages. This takes no account of the extreme torment suffered during the 30% of the year. It should be noted that the Planning Authority took account of 100% directional use when developing the Noise Zones to ensure that on any given day that no new dwelling would be exposed to high levels of noise. Unfortunately, neither ANCA nor the Planning Authority applied this same logic to existing dwellings. The Planning Authority has deemed it a serious health risk for any new dwellings in Zone A, yet they see it as ok to inflict this same level of noise on existing dwellings in Zone A. This is a serious issue, and the noise zones show that existing dwellings in Zone A should be afforded immediately relief from the severe noise levels. Failure to do so contravenes the Fingal Development Plan.

Notwithstanding the complexity of this application, we urge the Board to make a swift decision on this case. The local communities are suffering severe physical health, mental health and emotional health issues in relation to ongoing breaches by the daa of planning conditions imposed by the Board in 2007 when granting permission for the North Runway. How many breaches of planning are acceptable by the Board? Why are the daa allowed to carry on with impunity? An Bord Pleanála has a duty to ensure all planning and environmental laws are respected in their decision making. They also should take into account the proven track record of the daa breaching the very conditions laid down by the Board.

Previous submissions to the Planning Authority and ANCA from the '*St Margaret's The Ward Residents Group*' included relocation options for the dwellings most impacted by noise and where ANCA's decisions would leave these people vulnerable to the adverse effects of Aircraft Noise. An Bord Pleanala have the power to remove/amend the night-time restrictions and therefore the onus is on the Board to find a safe environment for these people and their families to live. In their current draft decision, the Board have not explored relocation options or taken on board the residual health effects and costs associated with their decision. The community has proposed Thornton Hall as such a site that would be acceptable to the community and the Board could make such a recommendation to explore this option in depth. To finance this relocation scheme, the community has advocated an increase to the passenger charge imposed on travellers along the lines of the '***Polluter Pays'*** principal. The monies raised from such a charge could be ring fenced to purchase Thornton Hall or equivalent site and provide housing for the displaced residents. The cost is borne by the 'Polluter' and not by Government or the daa. The community most impacted knows that it cannot stand in the way of Dublin Airport but it wants proper recognition for the harms inflicted on them and for the community to be provided with proper relocation so they can continue to live amongst their community and families. The option of

voluntary purchase is meaningless if you are displaced from your family and community.

In conclusion, we call on An Bord Pleanála to reject this Planning application and regulatory decision as there's no justification for it except inflicting health costs and carbon costs on the public. Planning is an afterthought for the daa. Their actions show they do not respect the decisions of the Board. It is 2 years now since the North Runway opened. Fingal County Council has taken enforcement proceedings against the daa in relation to the breach of Condition 5 (65 nighttime flights). The Council is also investigating the alleged illegal divergent flight paths off the North Runway. Unfortunately, for residents, the Council seems incapable of coming to a swift decision and appears to be waiting on the Board's decision in this Relevant Action application. It is therefore of upmost importance that the Board makes a decision in a timely manner to refuse permission for the Relevant Action application.

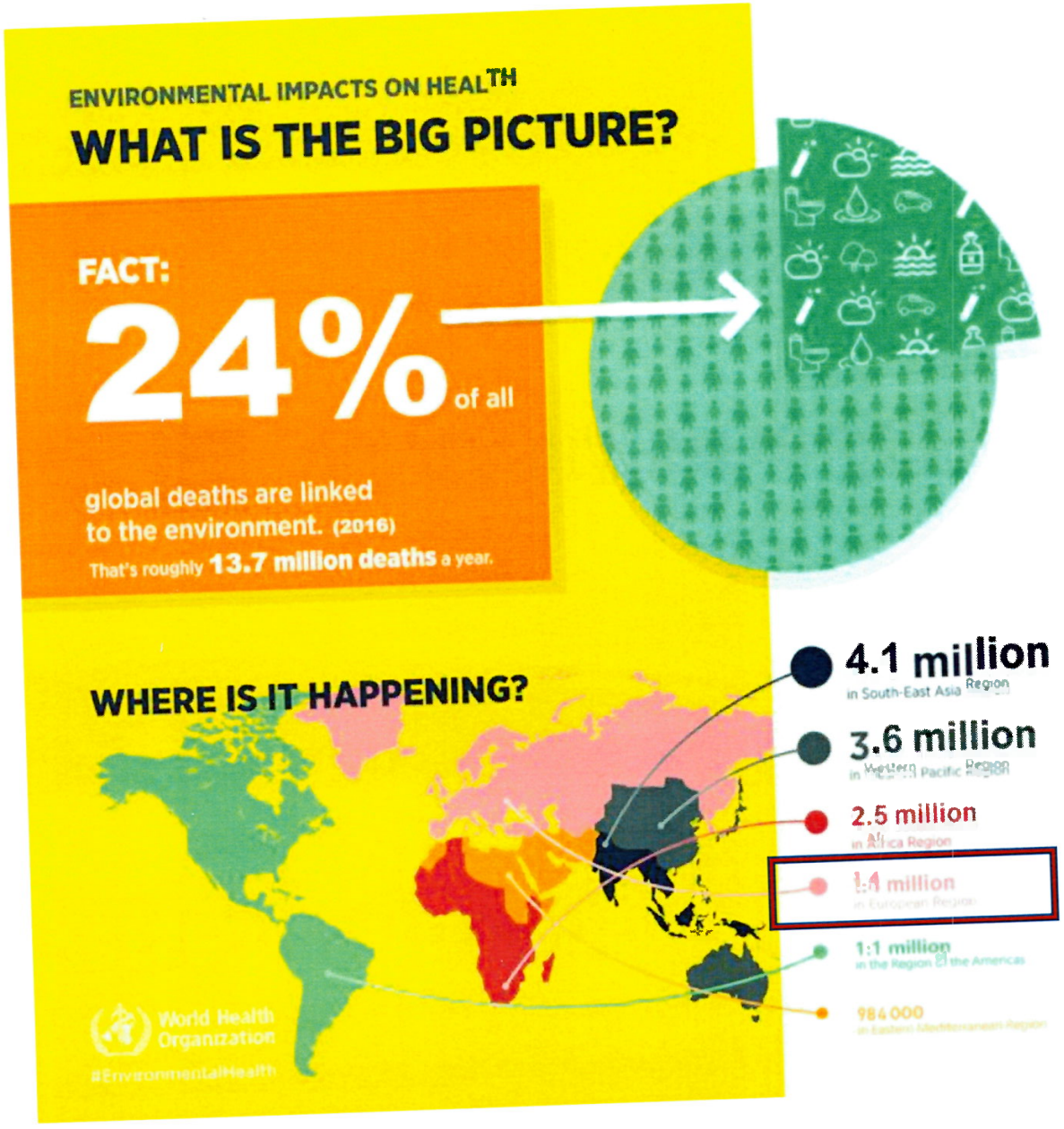
Adverse health consequences of noise

uecna
European Union Against Aircraft Nuisances

JG|U UNIVERSITÄTSmedizin. MAINZ

Omar Hahad
University Medical Center Mainz, Germany
Department of Cardiology, Cardiology I
24th of June 2024

The environment is important



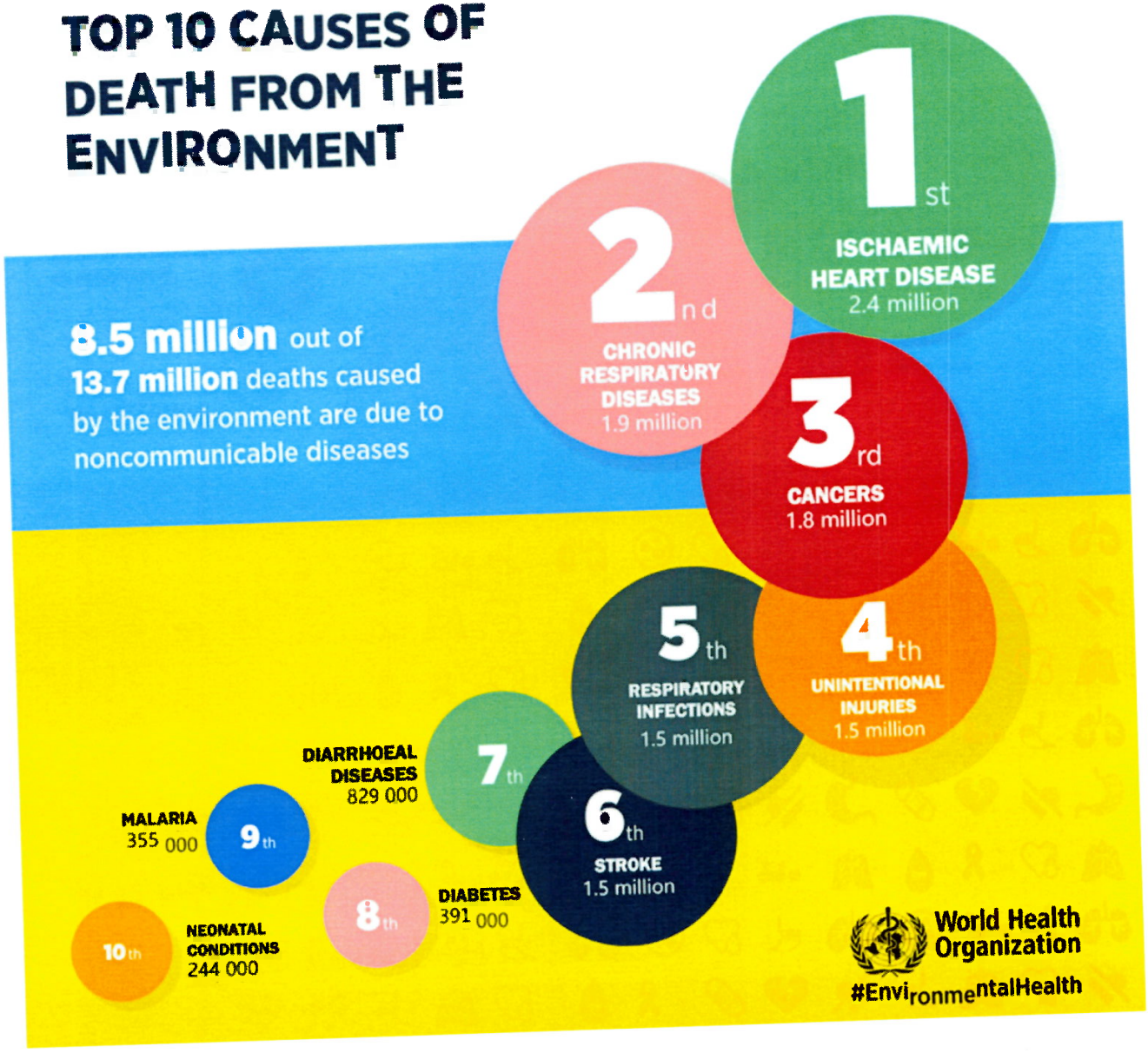
https://www.who.int/activities/environmental-health-impacts

Environmental risk factors

https://www.who.int/activities/environmental-health-impacts

Environmental causes of death

https://www.who.int/activities/environmental-health-impacts



Who is at risk?

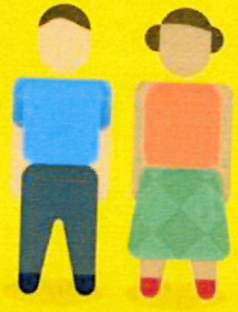
https:// www.who.int / activities /environmental- health -impacts

WHO IS MOST IMPACTED BY THE ENVIRONMENT

Environmental impacts on health are uneven across age and mostly affect the poor.

Children under five and adults between 50 and 75 years old are most affected by the environment.

Low- and middle-income countries bear the greatest share of environmental disease.



Men
are slightly more affected due to occupational risks and injuries.

Women
bear higher exposures to traditional environmental risks such as smoke from cooking with solid fuels or carrying water.

YEARLY

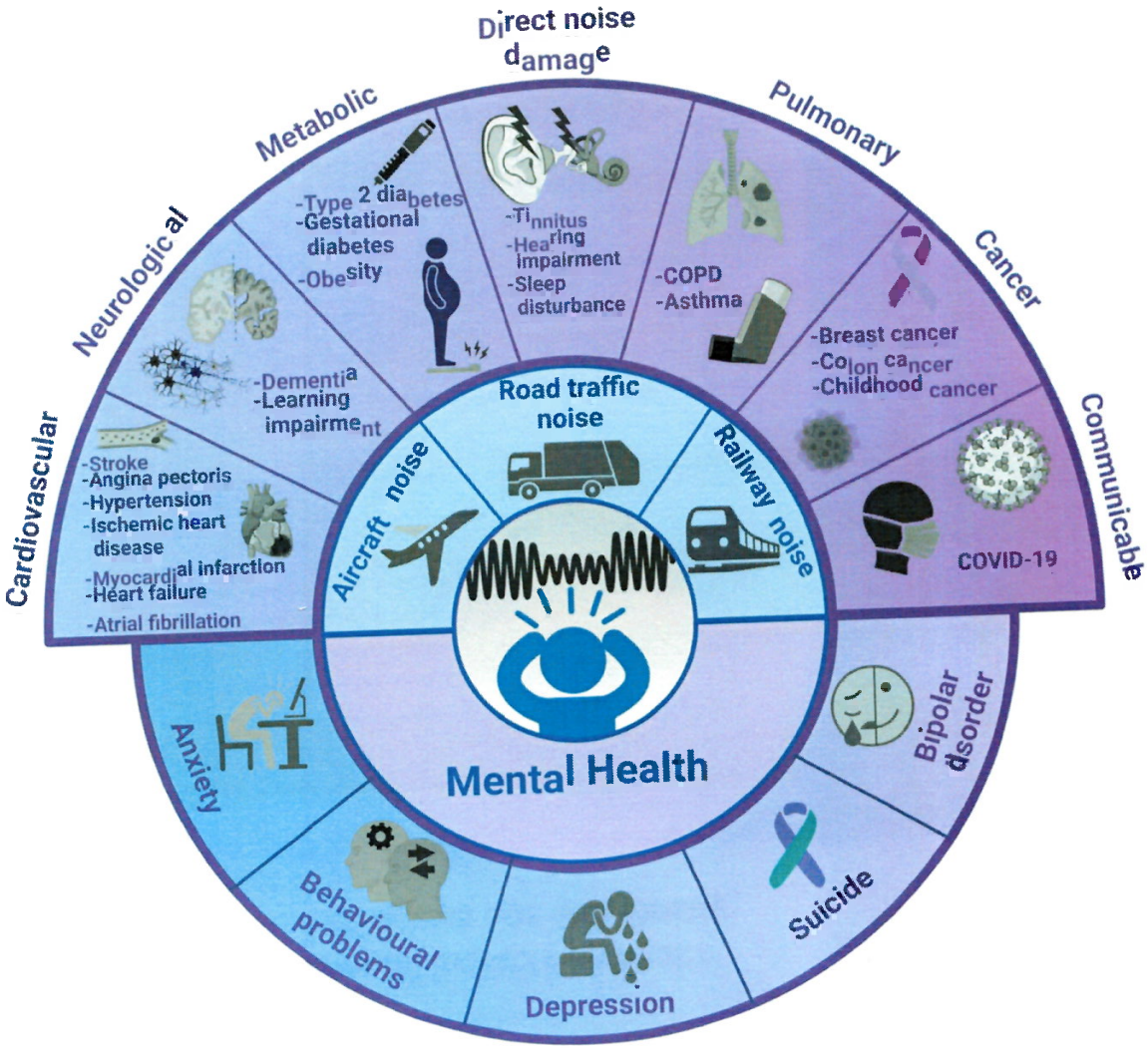
5.2 MILLION
Deaths in adults
between 50 and 75 years. The most common causes are noncommunicable diseases and injuries.

1.6 MILLION
Deaths in children
under five. The most prominent causes are lower respiratory infections and diarrhoeal diseases.

World Health Organization

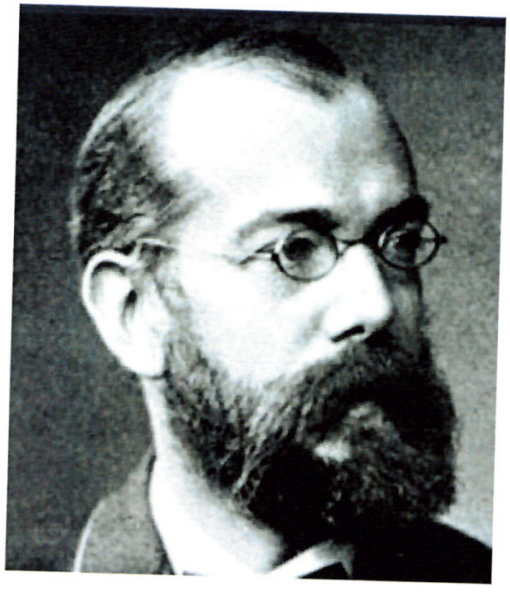
#EnvironmentalHealth

Is noise harmful to health?



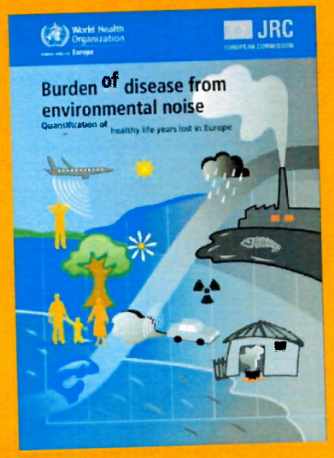
Hahad O et al. Noise and mental health: evidence, mechanisms, and consequences. J Expo Sci Environ, 2024.

Noise and health



„One day man will have to fight noise as fiercely as cholera and pest."

Nobel Prize winner Robert Koch (1910).

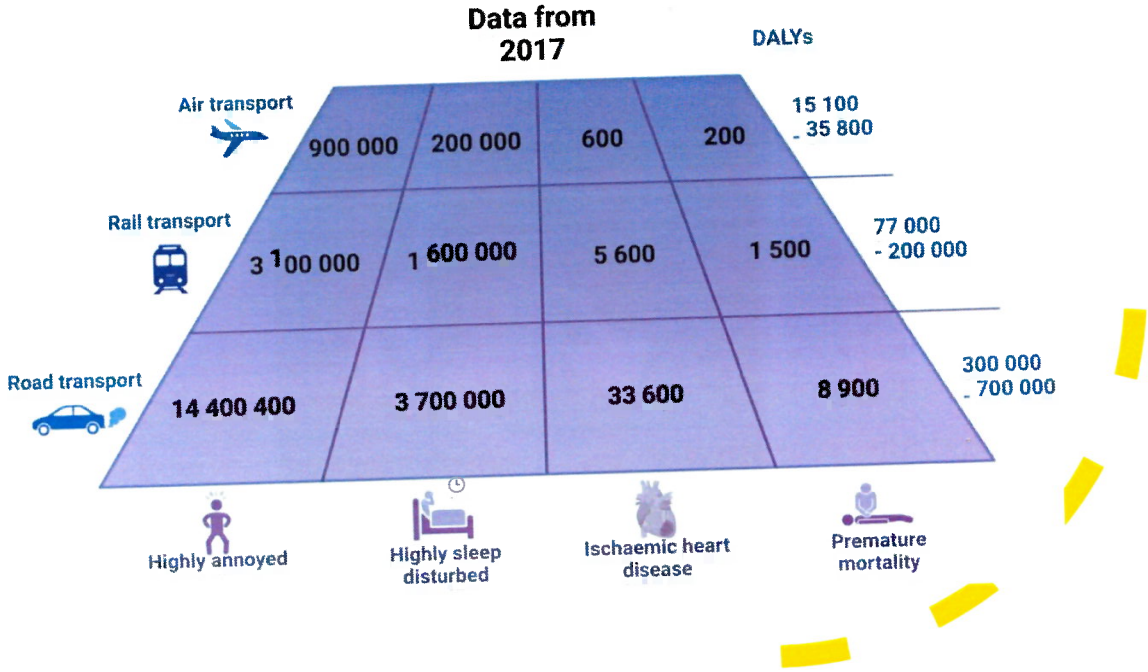


European Environment Agency

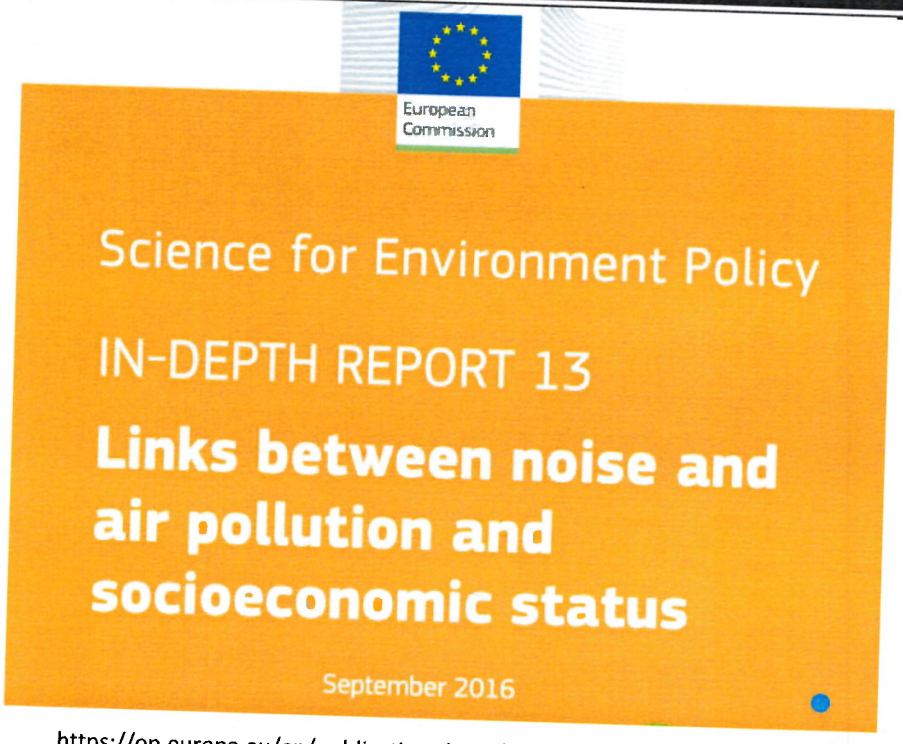
https://www.who.int/publications/i/item/9789289002295

https://www.eea.europa.eu/data-and-maps/figures/additional-information-on-health-impacts

Environmental noise causes the loss of up to **1.6 million healthy life years** (healthy life years lost due to illness, disability and premature death) in Western European countries every year



Noise rarely comes alone



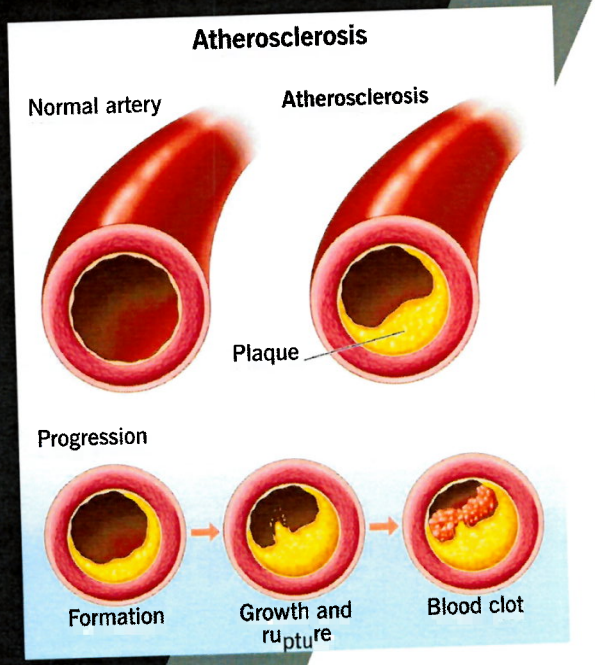
https://op.europa.eu/en/publication-detail/-/publication/1a3f0657-9a83-11e6-9bca-01aa75ed71a1/language-en

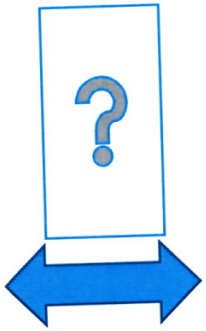
- Research suggests that the **social cost of noise and air pollution** in the EU - including death and disease — could be nearly **€1 trillion**.

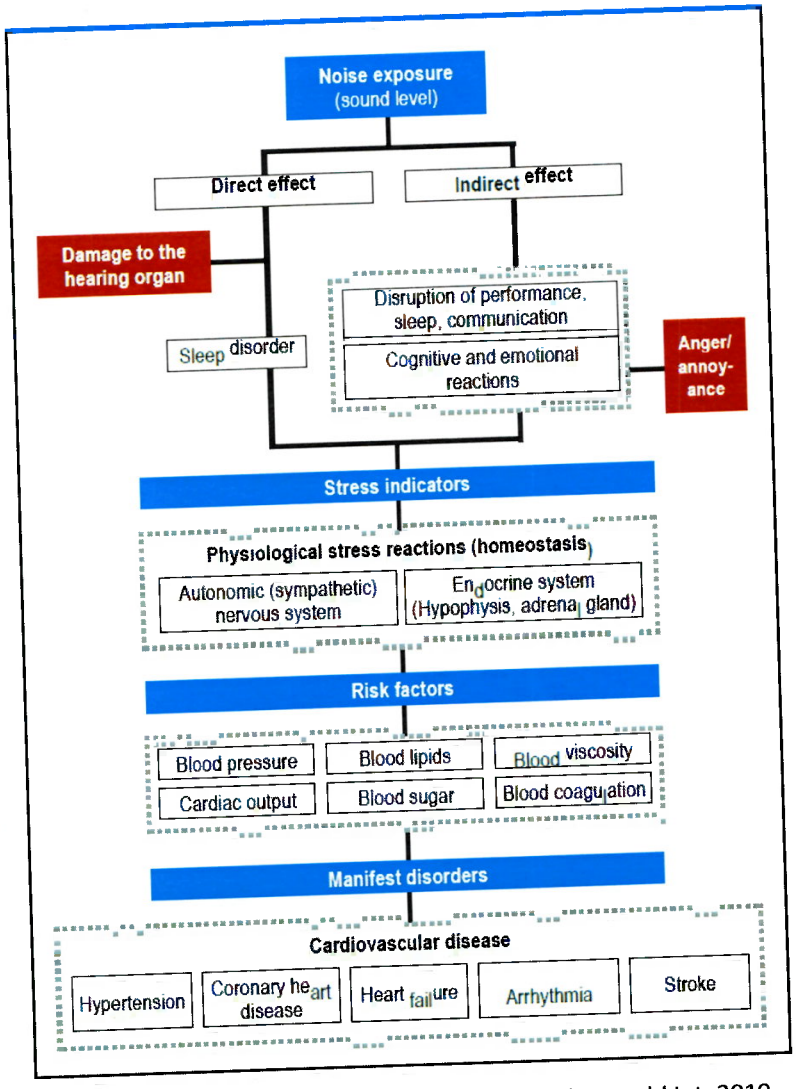
- For comparison, the social cost of **alcohol** in the EU has been estimated to be **€50-120 billion** and **smoking at €544 billion**.

How does noise make us sick?

Noise reaction scheme according to W. Babisch

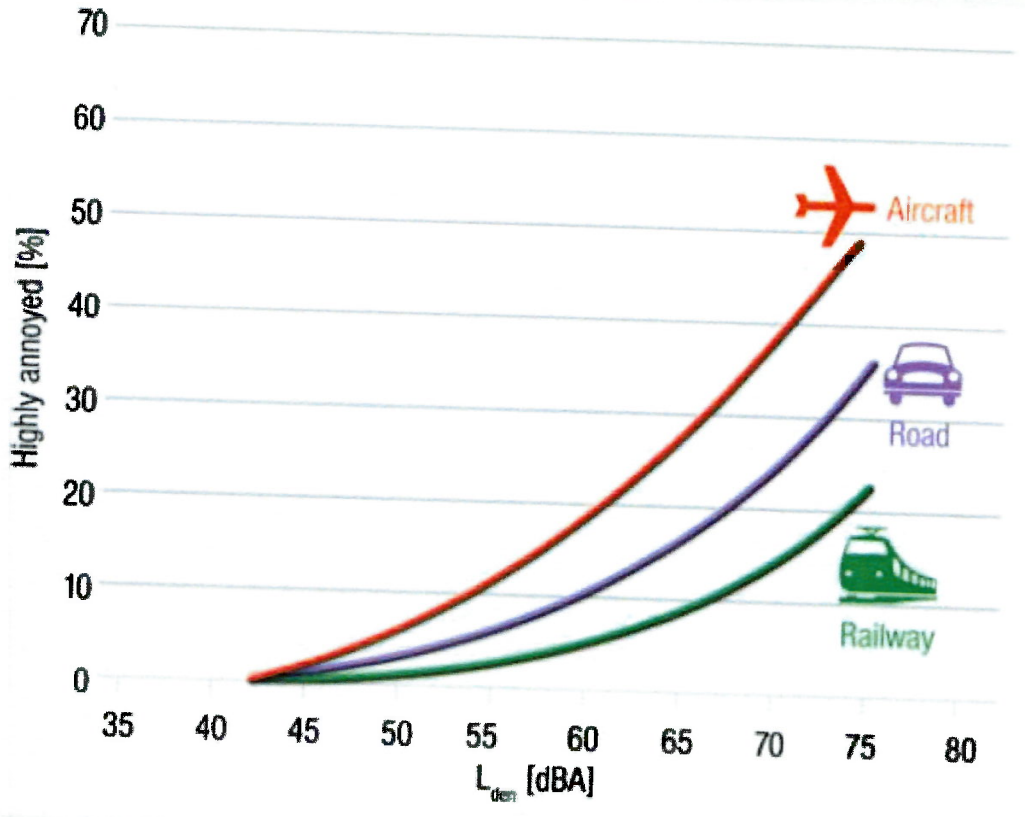






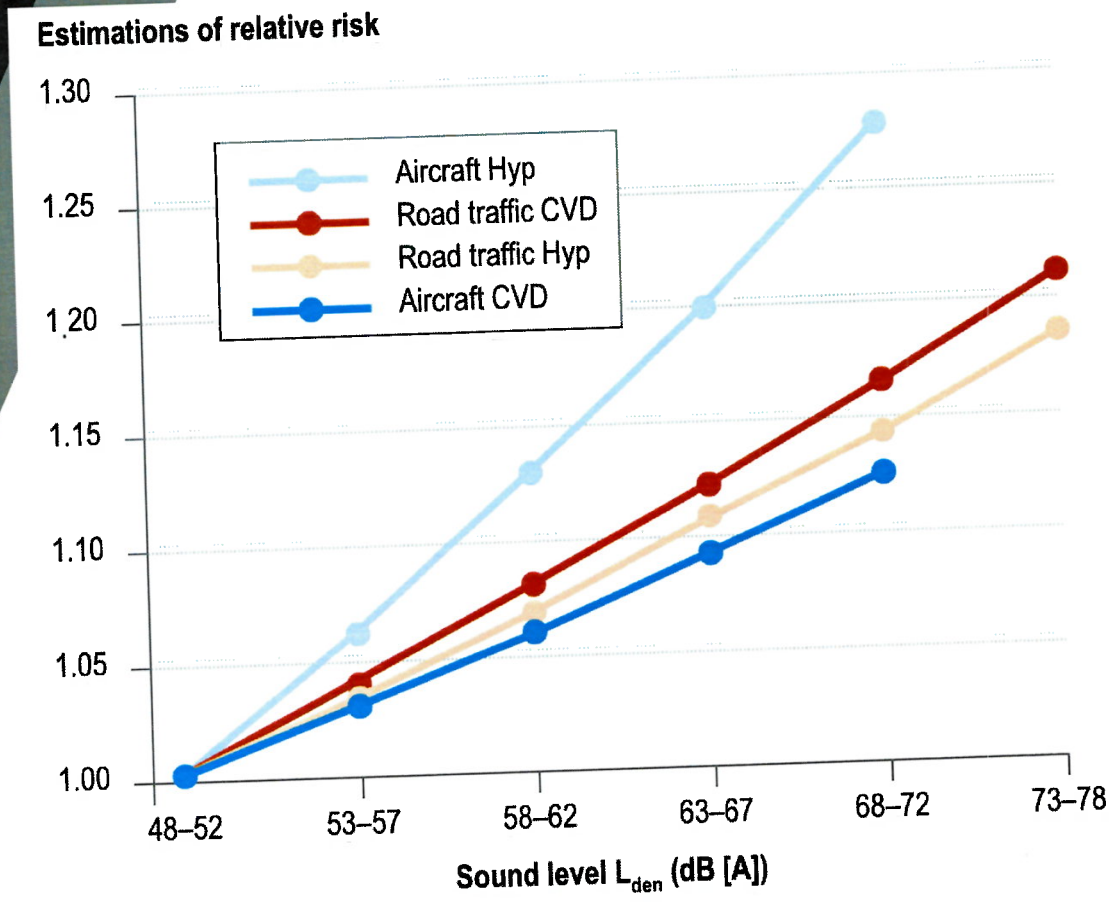
Hahad O et al. The Cardiovascular Effects of Noise. Dtsch Arztebl Int, 2019.

Aircraft noise bothers us the most



Münzel et al. Cardiovascular effects of environmental noise exposure. European Heart Journal, 2014.

Risk of high blood pressure and coronary heart disease due to aircraft noise

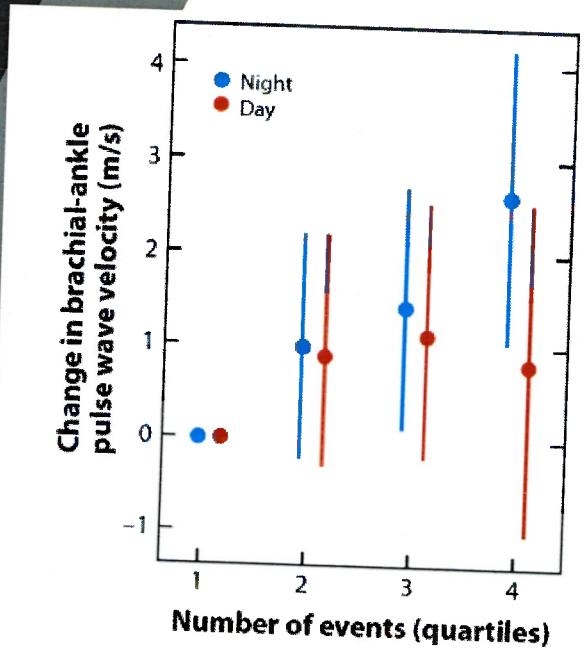


Hahad O et al. The Cardiovascular Effects of Noise. Dtsch Arztebl Int, 2019.

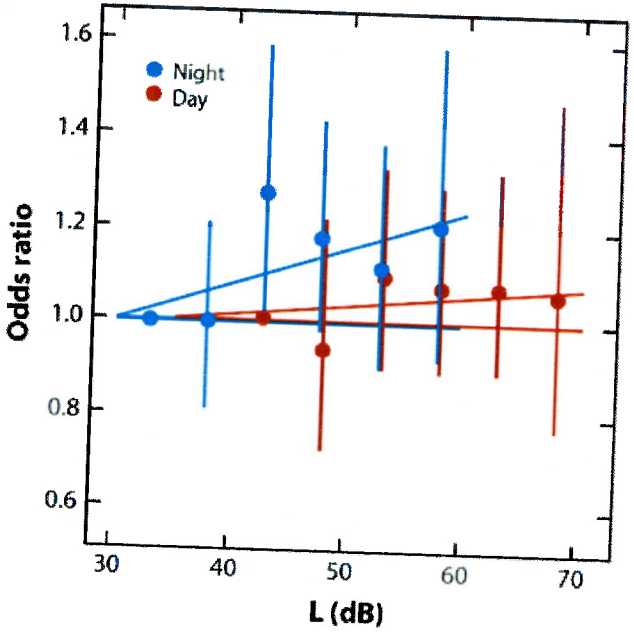
Important: Nocturnal aircraft noise

In particular, nighttime noise events (in blue) are responsible for increased vascular stiffness and high blood pressure compared to daytime noise events

Stiffness of the vessels



high blood pressure



Münzel T. et al. Adverse Cardiovascular Effects of Traffic Noise with a Focus on Nighttime Noise and the New WHO Noise Guidelines. 2020. Annual Reviews of Public Health .

Acute overflight and hypertension

European Heart Journal Advance Access published February 12, 2008

European Heart Journal
doi:10.1093/eurheartj/ehn013

CLINICAL RESEARCH

Acute effects of night-time noise exposure on blood pressure in populations living near airports

Alexandros S. Haralabidis[1], Konstantina Dimakopoulou[1], Federica Vigna-Taglianti[2], Matteo Giampaolo[3], Alessandro Borgini[4], Marie-Louise Dudley[5], Göran Pershagen[6], Gösta Bluhm[6], Danny Houthuijs[7], Wolfgang Babisch[8], Manolis Velonakis[9], Klea Katsouyanni[1]*, and Lars Jarup[5] for the HYENA Consortium

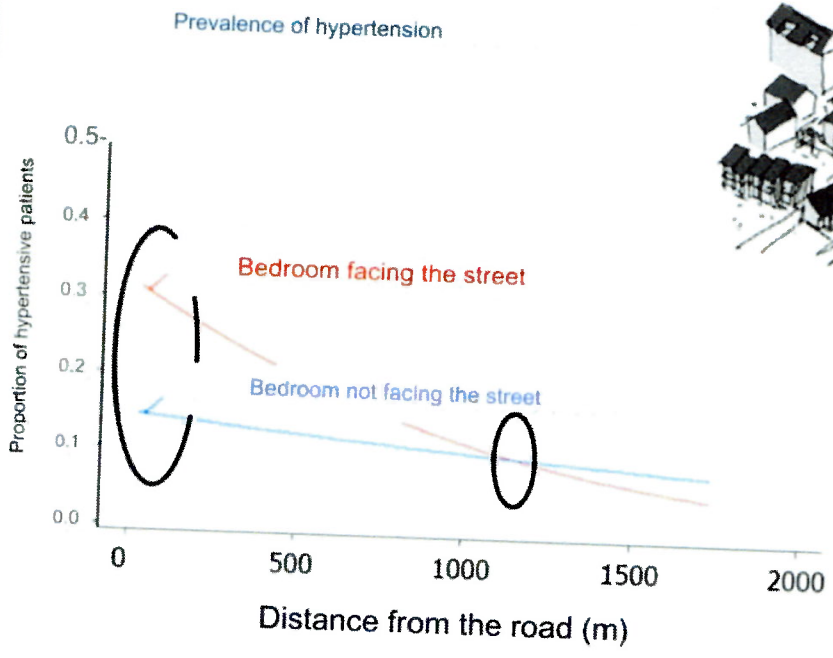
Aims Within the framework of the HYENA (hypertension and exposure to noise near airports) project we investigated the effect of short-term changes of transportation or indoor noise levels on blood pressure (BP) and heart rate (HR) during night-time sleep in 140 subjects living near four major European airports.

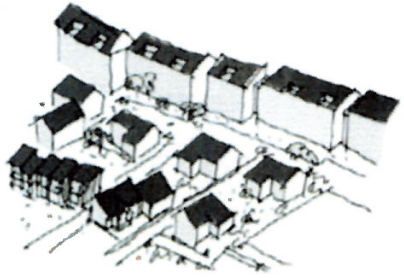
Methods and results Non-invasive ambulatory BP measurements at 15 min intervals were performed. Noise was measured during the night sleeping period and recorded digitally for the identification of the source of a noise event. Exposure variables included equivalent noise level over 1 and 15 min and presence/absence of event (with LAmax > 35 dB) before each BP measurement. Random effects models for repeated measurements were applied. An increase in BP (6.2 mmHg (0.63–12) for systolic and 7.4 mmHg (3.1, 12) for diastolic) was observed over 15 min intervals in which an aircraft event occurred. A non-significant increase in HR was also observed (by 5.4 b.p.m.). Less consistent effects were observed on HR. When the actual maximum noise level of an event was assessed there were no systematic differences in the effects according to the noise source.

Conclusion Effects of noise exposure on elevated subsequent BP measurements were clearly shown. The effect size of the noise level appears to be independent of the noise source.

Keywords Environmental noise • Blood pressure • Night-time sleep • Acute effects • Epidemiological study

Room orientation and high blood pressure





Lercher et al. (2000)

Insufficient sleep adversely affects both physical and mental well-being

European Heart Journal (2011) 32, 1484–1492
doi:10.1093/eurheart/ehr007

CLINICAL RESEARCH
Prevention/epidemiology

Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies

Francesco P. Cappuccio[1*†], Daniel Cooper[1], Lanfranco D'Elia[2], Pasquale Strazzullo[2], and Michelle A. Miller[1†]

[1]Warwick Medical School, University of Warwick, CSB Building, UHCW Campus, Clifford Bridge Road, Coventry CV2 2DX, UK and [2]Department of Clinical and Experimental Medicine, Federico II Medical School, University of Naples, Naples, Italy

Received 2 August 2010; revised 14 December 2010; accepted 11 January 2011; online publish-ahead-of-print 7 February 2011

Journal of Adolescent Health
Volume 66, Issue 5, May 2020, Pages 567-574

Original article

Sleep Disturbance Predicts Depression Symptoms in Early Adolescence: Initial Findings From the Adolescent Brain Cognitive Development Study

Aimée Goldstone Ph.D. [a,*], Harold S. Javitz Ph.D. [a], Stephanie A. Claudatos [a], Daniel J. Buysse M.D. [b], Brant P. Hasler Ph.D. [b], Massimiliano de Zambotti Ph.D. [a], Duncan B. Clark M.D., Ph.D. [b], Peter L. Franzen Ph.D. [b], Devin E. Prouty Ph.D. [a], Ian M. Colrain Ph.D. [a,c], Fiona C. Baker Ph.D. [a,d]

Nighttime aircraft noise around Zurich Airport

→The study found that the risk of cardiovascular death increases by 33 percent with nighttime noise levels betwee 40-50 decibels and by 44 percent with noise levels of 55 decibels.

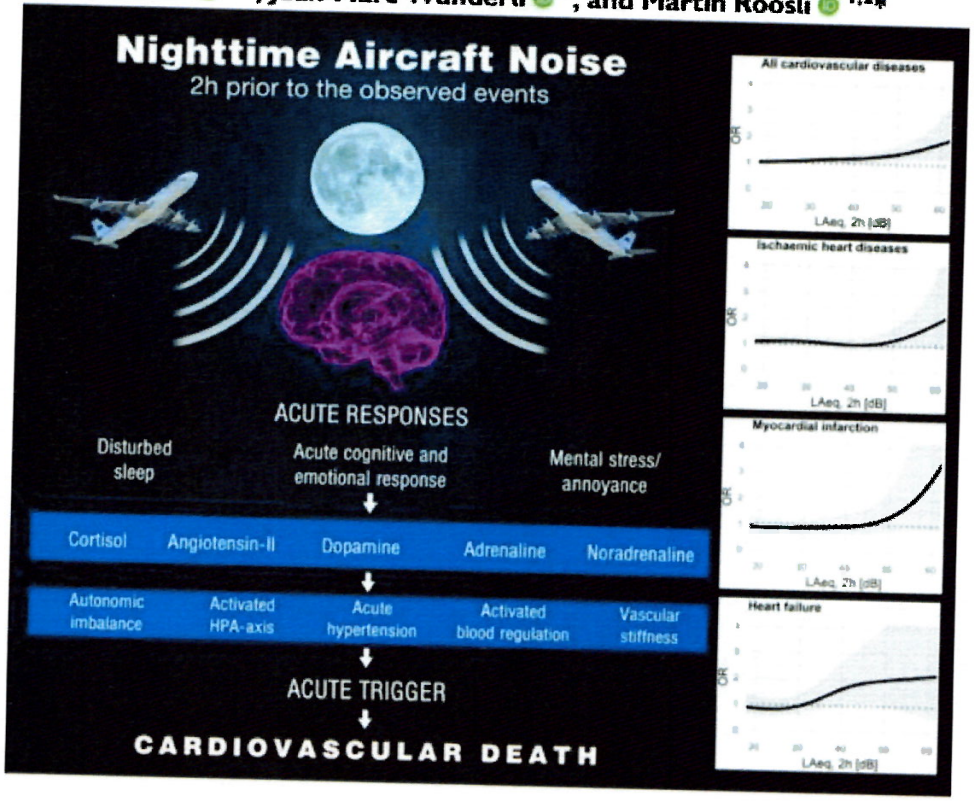
ESC European Society of Cardiology

European Heart Journal (2020) 00, 1–9
doi:10.1093/eurheart/ehaa957

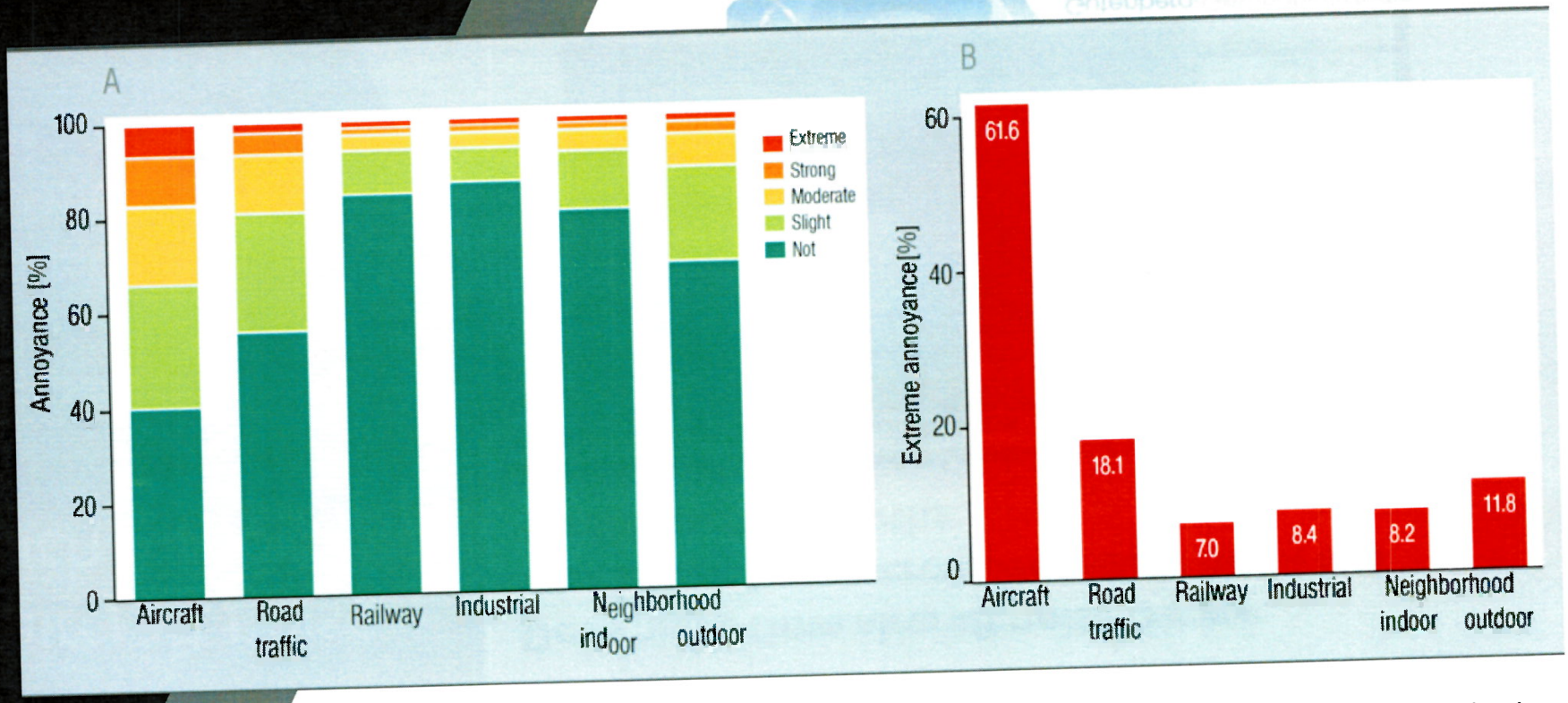
CLINICAL RESEARCH
Epidemiology

Does night-time aircraft noise trigger mortality? A case-crossover study on 24 886 cardiovascular deaths

Apolline Saucy [1,2], Beat Schäffer [3], Louise Tangermann [1,2], Danielle Vienneau [1,2], Jean-Marc Wunderli [3], and Martin Röösli [1,2]*



Our noise studies: Aircraft noise is dominant



Aircraft noise accounts for the largest share of total extreme noise pollution (right figure).

Aircraft noise annoyance in the general population

→more depression
→more atrial fibrillation

PLOS ONE

RESEARCH ARTICLE

Noise Annoyance Is Associated with Depression and Anxiety in the General Population- The Contribution of Aircraft Noise

Manfred E. Beutel[1]*, Claus Jünger[2], Eva M. Klein[1], Philipp Wild[3,4,5], Karl Lackner[6], Maria Blettner[7], Harald Binder[7], Matthias Michal[1], Jörg Wiltink[1], Elmar Brähler[1], Thomas Münzel[2]

1 Department of Psychosomatic Medicine and Psychotherapy, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany, 2 Medical Clinic for Cardiology, Angiology and Intensive Care Medicine, University Medical Center of the Johannes Gutenberg University Mainz, Mainz, Germany, 3 Preventive Cardiology and Preventive Medicine, Department of Medicine 2, University Medical Center of

International Journal of Cardiology 264 (2018) 79–84

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Annoyance to different noise sources is associated with atrial fibrillation in the Gutenberg Health Study

Omar Hahad [a], Manfred Beutel [b], Tommaso Gori [a], Andreas Schulz [c], Maria Blettner [d], Norbert Pfeiffer [e], Thomas Rostock [h], Karl Lackner [f], Mette Sørensen [g], Jürgen H. Prochaska [a], Philipp S. Wild [a], Thomas Münzel [a,*]

[a] Center of Cardiology, Cardiology I, University Medical Center of the Johannes Gutenberg-University Mainz and DZHK Standort Rhein-Main, Mainz, Germany
[b] Department of Psychosomatic Medicine and Psychotherapy, University Medical Center of the Johannes Gutenberg-University Mainz, Germany
[c] Preventive Cardiology and Preventive Medicine, Department of Medicine II, University Medical Center of the Johannes Gutenberg-University Mainz, Germany
[d] Institute of Medical Biostatistics, Epidemiology & Informatics, University Medical Center of the Johannes Gutenberg-University Mainz, Germany
[e] Department of Ophthalmology, University Medical Center Mainz, Germany
[f] Institute of Clinical Chemistry and Laboratory Medicine, University Medical Center of the Johannes Gutenberg-University Mainz, Germany
[g] Danish Cancer Society Research Center, Copenhagen, Denmark
[h] Center of Cardiology, Cardiology I, University Medical Center of the Johannes Gutenberg University Mainz, Germany

Field Study 1

European Heart Journal (2013) 34, 3508–3514
doi:10.1093/eurheartj/eht269

CLINICAL RESEARCH

Effect of nighttime aircraft noise exposure on endothelial function and stress hormone release in healthy adults

Frank P. Schmidt[1], Mathias Basner[2], Gunnar Kröger[1], Stefanie Weck[1], Boris Schnorbus[1], Axel Muttray[3], Murat Sariyar[4], Harald Binder[4], Tommaso Gori[1], Ascan Warnholtz[1], and Thomas Münzel[1]*

[1]Department of Medicine II, University Medical Center, Johannes Gutenberg University Mainz, Langenbeckstrasse 1, 55131 Mainz, Germany; [2]Unit of Experimental Psychiatry, Division of Sleep and Chronobiology, Department of Psychiatry, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, USA, [3]Institut für Arbeits-, Sozial- und Umweltmedizin, University of Mainz, Mainz, Germany; and [4]Institute for Medical Biometry, Epidemiology and Informatics, University of Mainz, Mainz, Germany

Received 31 January 2013; revised 6 June 2013; accepted 20 June 2013; online publish-ahead-of-print 2 July 2013

Noise scenarios

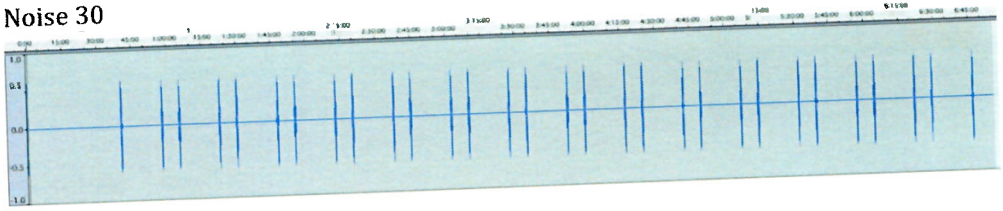
- **75 healthy subjects were** exposed to **simulated nighttime aircraft noise** at home while they slept

- **3 scenarios** : control scenario (no noise exposure), Noise30 (30 aircraft noise events) and Noise60 (60 aircraft noise events)

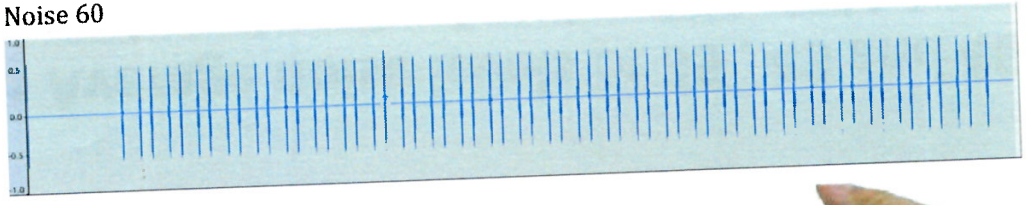
- **Average noise levels** of **35** , **43** and **46 dB(A)** and **peak noise levels of 60 dB(A**)

Setting

Noise 30



Noise 60

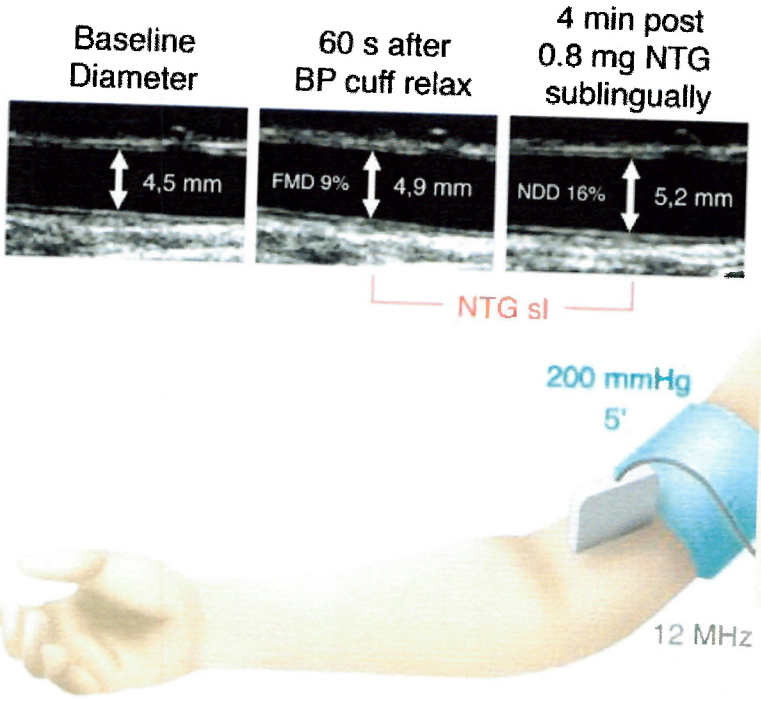


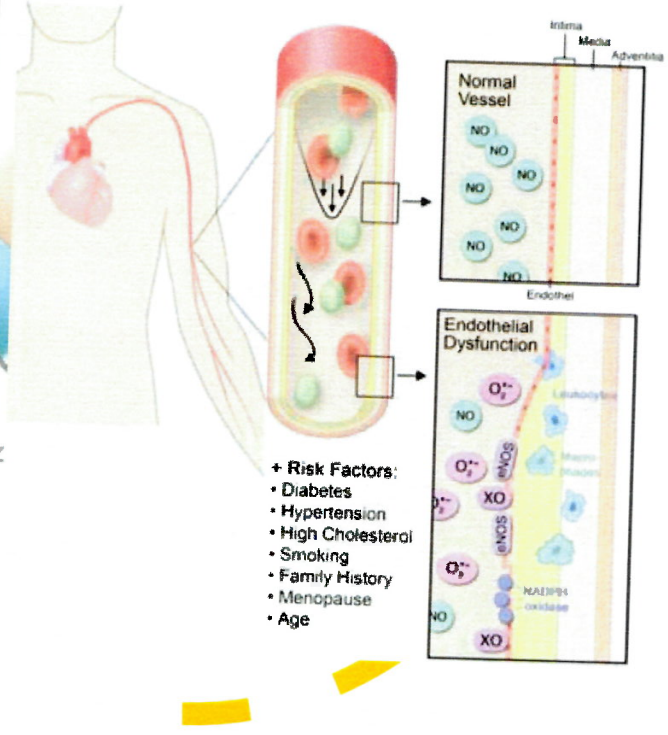
Noise scenaric

Polygraphy

Player

Measurement of vascular endothelial function





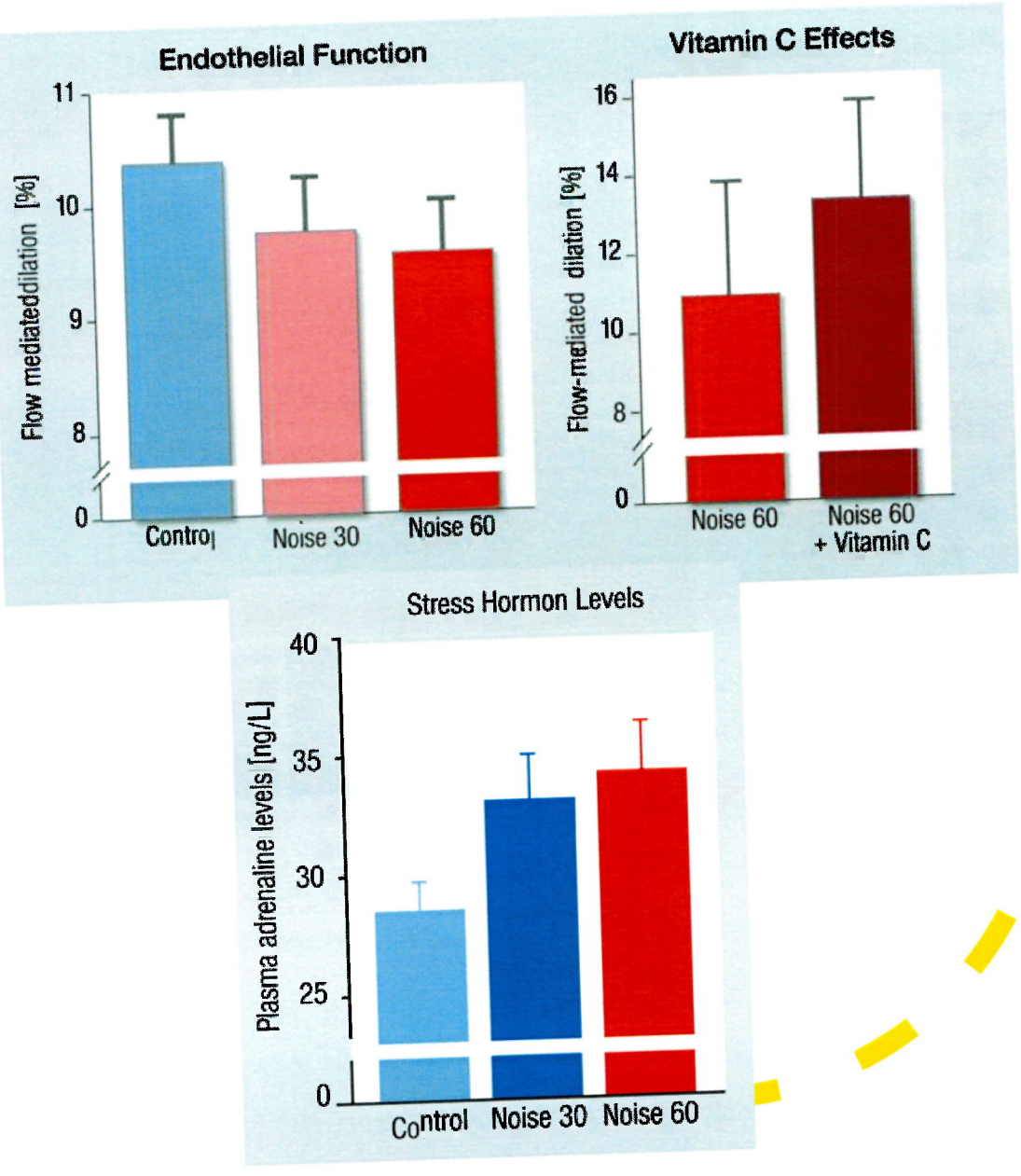
Results :

Significant deterioration in **sleep quality**

Increased release of **adrenaline**

Deterioration in **endothelial function**

Interesting: **Vitamin C** improves vascular function after noise exposure



Field Study 2: Patients with coronary heart disease

In patients with existing coronary heart disease, the aircraft noise effects were significantly more pronounced

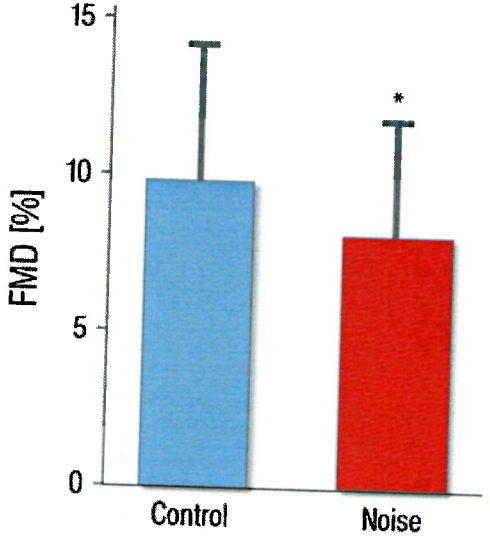
Clin Res Cardiol (2015) 104:23–30
DOI 10.1007/s00392-014-0751-x

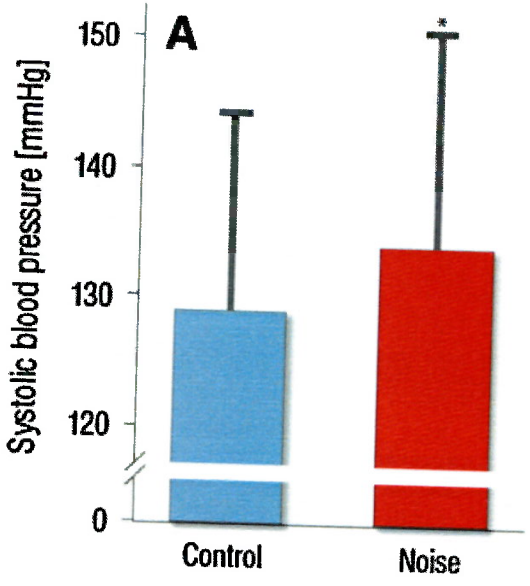
ORIGINAL PAPER

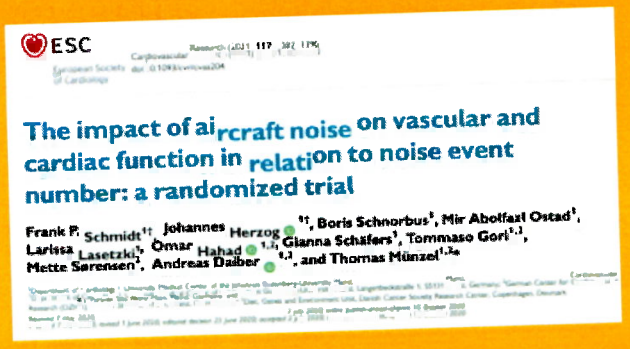
Nighttime aircraft noise impairs endothelial function and increases blood pressure in patients with or at high risk for coronary artery disease

Frank Schmidt · Kristoffer Kolle · Katharina Kreuder · Boris Schnorbus · Philip Wild · Marlene Hechtner · Harald Binder · Tommaso Gori · Thomas Münzel

Received: 25 June 2014 / Accepted: 1 August 2014 / Published online: 22 August 2014





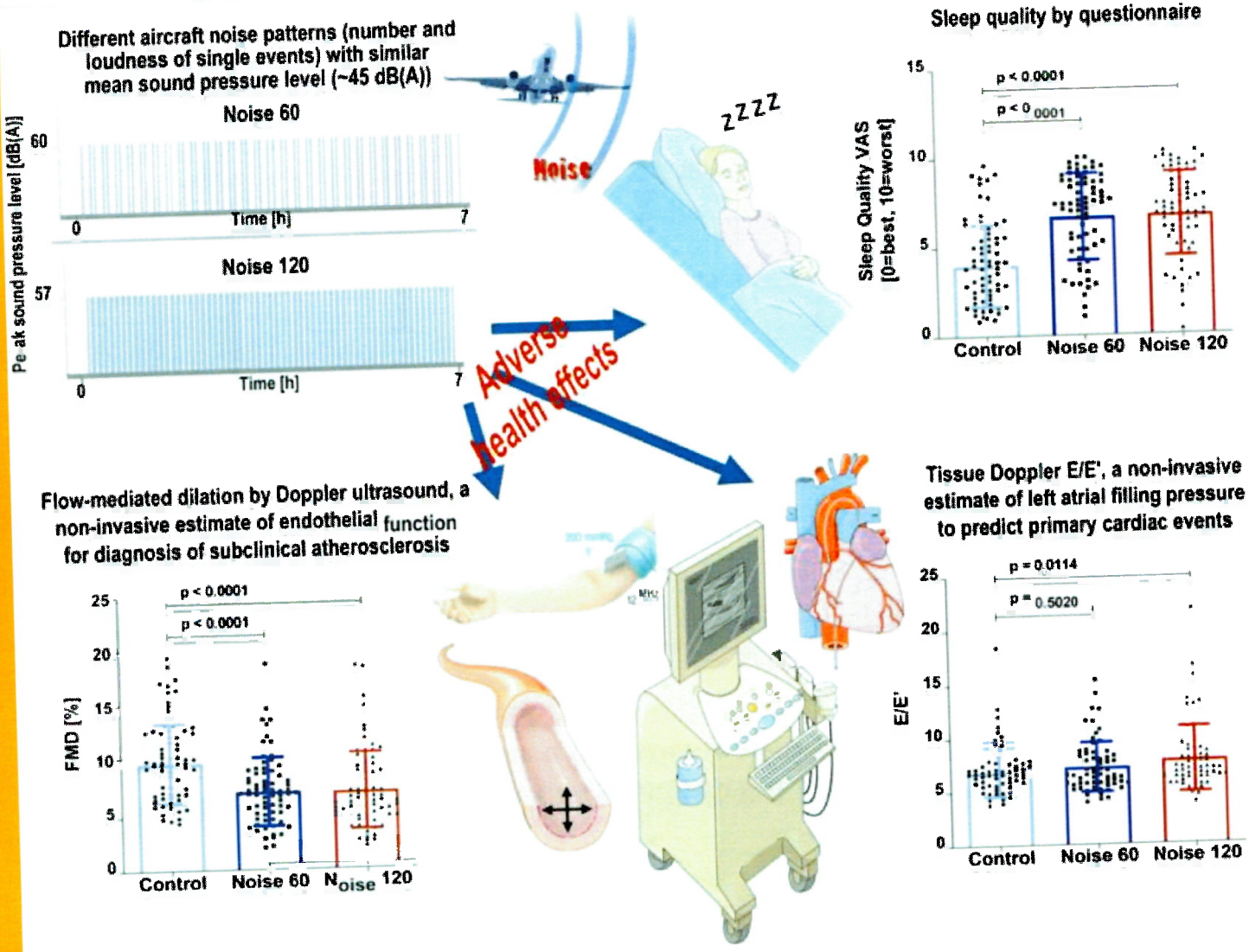

ESC

The impact of aircraft noise on vascular and cardiac function in relation to noise event number: a randomized trial

Frank P. Schmidt[†], Johannes Herzog[†], Boris Schnorbus[†], Mir Abolfazl Ostad[†], Larissa Lasetzki[†], Omar Hahad[†], Gianna Schäfers[†], Tommaso Gori[†], Mette Sørensen[†], Andreas Daiber[†], and Thomas Münzel[†]

Field Study 3: Little loud vs. many quiet Aircraft noise events

result in comparable damage



What we need:

- Noise should be officially recognized as a manifest (cardiovascular) risk factor
- Integration into medical guidelines for prevention
- Legal regulation in line with WHO limits
- Restriction of nighttime noise (no-fly times, etc.)

Thank you for your attention

The Influence of Night-time Noise on Sleep and Health

Gezondheidsraad **President**
Health Council of the Netherlands

To the State Secretary for Housing, Spatial Planning and the Environment
PO Box 20951
2500 EZ The Hague

Subject	: Report on night-time exposure to noise
Your reference	: LMV 2003003076
Our reference	: U 1007/WP/718-K
Enclosures	: 1
Date	: 22 July 2004

Mr State Secretary,

Further to your letter, reference LMV 2003003076, I am pleased to enclose an advisory report on night-time exposure to noise. At my request, the report has been drawn up by a specially formed Health Council Committee. The report has been reviewed by the Standing Committee on Medicine and the Standing Committee on Health and Environment.

The report is based upon the compiling Committee's assessment of the findings of available scientific research into the influence that night-time exposure to noise has on sleep and health. In order to obtain a good overview of the relevant themes, the Committee began its deliberations with a workshop for experts from the Netherlands and other countries. The workshop took place on 2 July 2003 as part of the *8th International Congress on Noise as a Public Health Problem* (ICBEN2003) in Rotterdam. In addition, interested parties were invited—both in direct correspondence from myself and in an advertisement placed in the *Government Gazette* of 22 July 2003—to submit any information that they felt might be helpful to the Committee. The Committee took account of the eleven responses to this invitation that were received when preparing its report, and each respondent received an individual reply from the Committee.

The Committee paid particular attention to the strength of the evidence for a link between exposure to night-time traffic noise and increased risk of hypertension. Almost all the studies that have looked at hypertension and ischemic cardiovascular disease have focused exclusively on associations with noise exposure *during the daytime and evening*. A recent study, to which you also made reference in your letter, has suggested that night-time noise and its effects on and during sleep are much more significant than daytime noise for the development of hypertension. Although the Committee considers it plausible that a causal relationship exists between exposure to *night-*

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The Netherlands
www.gr.nl

time noise and increased risk of hypertension, the Committee has concluded that the evidence for such a relationship is limited.

The Committee has noted that very little is known about the biological effects on children of exposure to noise when sleeping, or about the impact on children's health and well-being. The findings of the European research project *Road traffic and Aircraft Noise exposure and children's Cognition and Health* (RANCH) are due to be published shortly (probably in the summer of 2004). However, the Dutch participants in this project point out that these results will not entirely eliminate our lack of knowledge regarding the issue of childhood exposure to noise when sleeping.

I am also sending a copy of the enclosed advisory report to the Minister of Health, Welfare and Sport and another to the State Secretary for Transport, Public Works and Water Management.

Yours sincerely,
(signed)
Professor JA Knottnerus

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The Influence of Night-time Noise on Sleep and Health

to:

the State Secretary of Housing, Spatial Planning & the Environment

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Why this report?

Sleep is very important. It is therefore understandable that unintentional noise-related disturbance of sleep is a serious problem. Since it is not always easy to reduce disturbing noise, which is frequently associated with activities that are of value to the community at large, such as travel and transport, a debate has arisen regarding the health and well-being implications of sleep disturbance by environmental noise.

Like other countries, the Netherlands has regulations designed to limit public exposure to environmental noise, primarily with a view to managing the associated nuisance. Most of the limits relate to exposure over a complete twenty-four-hour period and do not therefore focus specifically on the period during which most people sleep. However, regulations are presently being prepared at EU level that do concentrate on night-time noise exposure. In due course, Dutch law will be brought into line with the new EU legislation.

Against this background, the State Secretary for Housing, Spatial Planning and the Environment wrote to the Health Council on 3 February 2003, asking for its advice regarding the influence of night-time noise on sleep, health and well-being. This report has been compiled by the Council's Noise, Sleep and Health Committee and addresses the questions posed by the State Secretary.

Exposure to night-time noise when sleeping

Environmental noise may originate from a wide variety of sources: air, road or rail traffic; industry and other localised activities; neighbours or one's general neighbourhood.

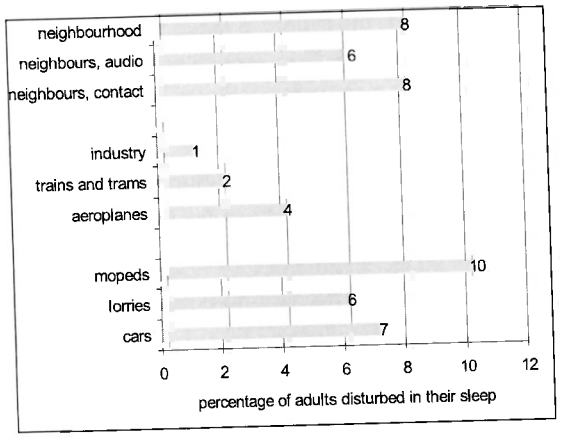
The consequences of exposure to night-time noise when sleeping have mainly been studied in relation to traffic noise. In the vast majority of cases, night-time traffic noise involves individually distinguishable noise events, such as the passage of a train, car or aeroplane.

Little research has been conducted into sleep disturbance from localised noise sources such as factories, firing ranges, shunting yards, wind turbines, climate control systems, building or demolition work. However, the Committee believes that the effects of noise from such sources are unlikely to differ essentially from the effects of traffic noise.

To date there has been no published research into a possible relationship between exposure to the other types of noise in the neighbourhood (recreational activities, children playing) and sleep disturbance. The Committee was therefore unable to assess the influence that such noise has on sleep.

Published research findings indicate that a variety of non-acoustical factors determine whether people are disturbed in their sleep by noises from neighbouring homes (voices, toilet flushing, footsteps, radio, television). The existence and complexity of these factors imply that it is not possible to establish meaningful relationships between night-time noise from neighbouring dwellings and the degree of sleep disturbance one suffers.

Research into the extent to which Dutch people claim to be disturbed by night-time noise during sleep is summarised below:



Effects of night-time noise during sleep

The Committee divided the effects of environmental noise during sleep into two general categories: biological responses and effects on health and well-being.

Biological responses to environmental noise occur because, even when asleep, an organism has to appraise and process stimuli from its environment. Such responses include waking up, having difficulty falling asleep again and increased motility.

It is plausible that, in the event of repeated exposure to night-time noise and under certain circumstances, some biological responses will have long-term implications for health and well-being. The Committee distinguishes five categories of effects:

- reduced sleep quality
- reduced general well-being
- impaired social interaction and reduced concentration during day-time
- specific disease symptoms
- loss of years of life (premature mortality).

Individuals differ from one another both in terms of their biological responses to night-time noise and in terms of the effects on their health and well-being. Thus, one person may take potentially harmful noise exposure levels in his or her stride without any significant adverse effects, while the health and well-being of someone else in a similar situation will deteriorate. In this context, much depends on the extent to which a variety of inherent and acquired personal factors interact with environmental factors.

Evidence

In order to assess the degree of certainty concerning the relationship between exposure to night-time noise and a particular effect, the Committee rates the available evidence as *sufficient*, *limited* or *insufficient*. Evidence is deemed sufficient if an indisputable relationship exists between exposure to night-time noise during the sleeping period and the effect in question, and if it is plausible from a biological model that the effect is attributable, at least in part, to the exposure. Evidence is rated as limited if a relationship between exposure and effect has been observed and a causal relationship is credible and plausible, but where the possibility of bias attributable to other factors cannot be excluded. The Committee also rates the evidence as limited when a relationship is plausible, and it has been observed that night-time noise exposure has an intermediary effect, which is known from other research to lead to the ultimate effect under consideration. Evidence is regarded as insufficient if the underlying research lacks the quality, consis-

tency or weight necessary to support a conclusion regarding the existence of a causal relationship.

Biological responses

There is sufficient evidence that night-time noise events cause direct biological responses, such as increased heart rate, reduced depth of sleep, increased motility and awakening.

Most biological responses begin to manifest themselves at an *SEL* in the bedroom of approximately 40 dB(A) (*LAmax* in the bedroom of at least 32 dB(A))*. Behavioural awakening (established by pressing a button) occurs when the bedroom *SEL* exceeds 55 dB(A).

The Committee also concludes that there is sufficient evidence of a relationship between exposure to night-time noise and a variety of biological responses exhibited before, during and after sleeping. Some of these are consequences of the direct responses already referred to: increased average heart rate, increased average level of motility, more frequent behavioural awakenings, and longer intervals of wakefulness. It additionally appears that average motility in people exposed to night-time traffic noise is greater at higher noise levels than might be expected on the basis of the direct responses. Higher levels of average motility are closely related to more frequent awakening, lower perceived sleep quality and increased daytime drowsiness.

Furthermore, there is sufficient evidence that people who, while attempting to sleep, are exposed to environmental noise or are concerned about being disturbed by noise in the night, have more difficulty falling asleep. After the sleep period, those who were exposed to night-time noise perceive the quality of their sleep to be impaired, find that their daytime mood is adversely affected and experience greater drowsiness, fatigue and irritability, especially in the morning.

There is limited evidence that under certain circumstances night-time noise can influence stress hormone levels. This effect was observed in women who were annoyed by noise at night and unable to protect themselves adequately to prevent the annoyance.

Implications for health and well-being

The Committee believes there is sufficient evidence that night-time noise has an adverse effect on quality of sleep and general well-being. Limited evidence exists that exposure to night-time noise has a negative impact on social interaction, on the performance of

* In acoustics, the following two values are employed to specify a noise event: *LAmax*, the maximum sound level during a noise event, and *SEL* (sound exposure level), a particular summation of all sound levels during a noise event.

concentration-sensitive tasks during the day, on specific complaints or disease symptoms and on loss of life years due to fatal accidents at work.

Reduced sleep quality is evident from studies on reduced self-reported sleep quality, difficulty falling asleep and remaining asleep, more frequent awakening during the night, shorter sleep periods and increased motility during sleep. A reduction in general well-being due to night-time noise is evident from self-reported sleep disturbance, self-reported health problems, use of sleeping pills and sedatives, and adversely affected daytime mood. Among older people in particular, the use of sleeping pills and sedatives is increased by night-time noise.

The medical conditions that may be linked to exposure to night-time noise are insomnia, high blood pressure and cardiac disease, as well as depression in females. Where insomnia is concerned, the Committee considers the evidence of a causal relationship as sufficient, while there is limited *indirect* evidence for the three latter conditions. There is also limited *indirect* evidence of an increased risk of involvement in a fatal accident at work as a result of sleeping problems and insomnia associated with exposure to night-time noise.

The Committee has estimated the extent of the impact of night-time noise on the health and well-being of the Dutch people in the year 2003 in terms of people who report to be highly sleep disturbed and people suffering from insomnia. The results have been based on data regarding cumulative night-time exposure to road, rail and aircraft noise, provided by the Netherlands National Institute for Public Health and the Environment (RIVM).

Effect	Prevalence in 2003 Number of people affected (thousands)
Self-reported high sleep disturbance	100-1000
Insomnia	10-100

The number of adults in the Netherlands in 2003 who reported to be highly sleep disturbed due to night-time traffic noise is between one hundred thousand and one million. The increase in the number of people with insomnia attributable to exposure to night-time traffic noise is estimated at 2 per cent of the number of people who reported to be highly sleep disturbed.

Using data on the specific exposures to road, rail and air traffic, the Committee estimates the number of adults who reported to be highly sleep disturbed to be more than 100,000 for each noise source (data for the year 2000; data for 2003 are not available as yet). This number for road traffic noise is about two to four times as large as the numbers for rail and aircraft traffic noise. The increased number of individuals with insom-

nia attributable to road and rail traffic noise amounts to between 1000 and 10,000 in each case. For air traffic noise in the region of Amsterdam Schiphol Airport the corresponding figure is between 100 and 1000 individuals.

Recently the collective burden of disease has been quantified in terms of *disability adjusted life years* or DALYs. Using data from an initial study by RIVM into the severity of various health effects, the Committee has calculated that high sleep disturbance resulting from traffic noise results in a burden of disease amounting to several tens of thousands of DALYs. The equivalent figure for insomnia is certainly an order of magnitude less than this. In spite of the uncertainties associated with such estimates, it does appear that, by affecting sleep, night-time traffic noise is one of the most important effects exerted by the physical environment on health.

Groups at higher risk

Direct cardiovascular responses to night-time noise may be more common in people with cardiovascular problems, people who consider themselves sensitive to noise, and in children. Due to lack of research, it is at present impossible to indicate whether children are possibly more sensitive than adults to other direct biological effects of night-time noise.

People with insomnia are at greater risk of biological effects due to night-time noise than good sleepers. Environmental noise exposure increases the time it takes to fall asleep, especially in people who are worried when they go to sleep. In addition, they also perceive their sleep quality as lower.

The Committee also considers it plausible that exposure to night-time noise is more likely to have an adverse effect on the health and well-being of the following groups: older people, pregnant women, women who have given birth within the preceding 12 months or so, people who regularly work at night, people with sleep disorders, physical pain, dementia, depression, hypertension, heart disease and pulmonary disease.

A special metric for night-time noise

In the Netherlands, special rules covering night-time noise are applied only in relation to scheduled overnight aircraft movements. However, from a scientific point of view, there is no reason why night-time noise from road traffic, rail traffic and industrial activities should be regarded as different from aircraft noise with respect to possible effects on health and well-being. In 1997, the Health Council recommended a system with two noise indicators to protect the public from traffic and industrial noise in the living environment. The Committee has taken up this proposal. According to the system put forward in 1997 the metric of exposure to noise over a twenty-four-hour period should be

representative of general annoyance, while the night-time noise metric should be related to sleep disturbance. Such an approach is rational since there is only a limited degree of comparison between the working mechanisms and effects of night-time noise on the one hand and general annoyance on the other hand.

In addition to *Lden*, the indicator of noise over a twenty-four-hour period, the European Union has adopted *Lnight*, an indicator to be used in the regulation of night-time noise. *Lnight* represents the noise exposure at the most exposed façade, calculated for an eight-hour night-time period (11pm to 7am), and averaged over a full year. In the calculations, more weight is given to the louder noise events than to the quieter ones. Since *Lnight* relates to the outdoor situation, the noise exposure in a person's bedroom may in practice be considerably higher than *Lnight* minus the average noise attenuation of a Dutch home. This is partly because homes differ considerably in the attenuation they provide (in the Netherlands, only newly built homes have to meet noise attenuation standards), and partly because most Dutch people choose to sleep with their bedroom windows at least slightly open. Furthermore, requirements on the basis of *Lnight* can never provide complete protection against sleep disturbance, since many Dutch people go to bed before 11pm and still more (roughly half of all adults) sleep beyond 7am.

Nevertheless, the Committee sees no benefit in adopting an alternative to *Lnight*, since it realises that it is impossible to address every conceivable factor by means of a regulatory noise metric. Furthermore, the Committee is of the opinion that regulations based on the use of *Lnight* (as well as *Lden*) could provide a considerable degree of protection against noise during sleep.

Additional metrics

In addition to setting standards based on *Lnight*, exposure limits could also be imposed on noise events, possibly by limiting the maximum permissible sound level or the number of events per night.

At a given *Lnight* value, the most unfavourable situation in terms of a particular direct biological effect of night-time noise is not, as might be supposed, one characterised by a few loud noise events per night. Rather, the worst scenario involves a number of noise events all of which are roughly 5 dB(A) above the threshold for the effect in question. Where motility is concerned, for example, the worst situation is one where all noise events have an *SEL* of roughly 45 dB(A) inside the bedroom. However, limiting the *SEL* inside the bedroom to less than the biological effect threshold levels is not a technically realistic option at the present time. Depending on how *Lnight* is regulated, one option might also be to limit the number of noise events.

An average adult experiences one or two 'spontaneous' behavioural awakenings during a typical night. The more noise events occur each night, the more likely it is that

a sleeper who awakens 'spontaneously' during an event will hear the noise, be annoyed by it, and then have trouble getting back to sleep. In extreme cases, a person can hear a noise up to ten times a night without being awoken by it. This would tend to argue in favour of limiting the number of events. Depending on the level to which *Lnight* is limited and the level of protection opted for, it could therefore be possible to limit the number of noise events (e.g. the number of trains, cars or aeroplanes per night). The effectiveness of applying such limits can only be estimated very roughly.

Adjustment of *Lnight* to take account of special noises

The Committee has considered the following 'special' environmental noises: low frequency noise (humming), noise containing low frequency components, tonal noise, impulse noise (noise that rapidly rises), industrial noise and sporadic but very loud noise events. Although little information is available concerning the influence on sleep of exposure to noise with these special characteristics, the Committee believes that there are reasons to assume that in some cases the effects are more pronounced than the effects of exposure to 'ordinary' traffic noise. In cases involving noise that contains low frequency components, tonal noise and impulse noise, the Committee suggests using the same adjustment factors for *Lnight* as proposed in the Health Council's 1997 report *Assessing Noise Exposure For Public Health Purposes*. Like its predecessor, the Committee is unable to propose an adjustment factor for low-frequency noise that consists entirely of humming, such as that associated with transformers and wind turbines. In cases involving noise from industrial activities, the Committee takes the view that research conducted since 1997 has shown that adjustments to match the effect of such noise to road traffic noise are not necessary.

It is not known whether sporadic but very loud noise events have any special consequences for sleep. The Committee is therefore unable to produce any scientifically based conclusion regarding these events.

Protective measures

In response to the State Secretary's question regarding ways in which the public may be protected against night-time noise, the Committee adopts the generally accepted environmental management and occupational health and safety strategies. Hence, the first step should be to reduce the noise at the source (and to reduce the number of sources), followed by measures designed to address the transfer of noise from the source to the 'receiver', and finally 'receiver-oriented' measures might be considered.

Many of the noise-reducing measures already in place are concerned primarily with limiting the impact of exposure to noise over a twenty-four-hour period. Additional

noise attenuation of the façade of bedrooms is one of the few measures that are taken to deal with night-time noise.

Little scientific research has been conducted into the effectiveness or efficiency of measures intended to protect against the consequences that either general noise exposure or night-time noise exposure has for health and well-being. Consequently, there is no sound scientific basis for making any statement regarding the effectiveness of any protective regime. Furthermore, increasing mobility is liable to offset the benefit that might be gained from many traffic noise reduction measures.

Furthermore, the Committee would like to emphasise the importance of instruction and communication as the final elements among the measures needed to keep the adverse effects of night-time noise within acceptable limits.

Often, there is no choice but to take both source-oriented and transfer-oriented measures, sometimes complemented by recipient-oriented measures. This is because – even disregarding the issues of effectiveness and efficiency – none of the possible forms of intervention is easy to implement. The Committee does not consider the introduction of personal hearing protectors an appropriate collective response to environmental noise, although such protectors may offer relief in specific cases.

Recommendations for future research

The Committee recommends that studies be carried out into various topics, in order to fill what it considers to be the most important gaps in our knowledge regarding exposure to night-time noise. These topics are the long-term effects of night-time noise on health and well-being, the effects of night-time noise on children, the effectiveness and efficiency of noise attenuation measures for façades and between dwellings, and the effects of noise produced by neighbours or by one's general neighbourhood. The Committee advocates that such studies be linked to international programmes, as the Health Council has indeed already proposed in its advisory report entitled *Gezondheid en milieu: Kennis voor beleid* (*Environmental Health: Research for Policy*).

Glossary of terms used in this report

Table 1 provides brief definitions of the terms used in this report. Several groups of terms are distinguished: terms relating to sleep and the measurement of sleep parameters, terms relating to the acute effects of exposure to night-time noise when sleeping, terms relating to health and well-being, and terms relating to the indexes of noise exposure used in this report.

Table 1 Glossary of general (sleep-related) terms, biological phenomena, terms relating to health and well-being, and indexes of noise exposure.

Term	Definition
General sleep-related terms	
Sleep inception time	The point in time when a person falls asleep.
Awakening time	The point in time when a person wakes up, as a precursor to arising and becoming active.
Sleep latency/inception period	The length of time taken to fall asleep, i.e. the interval between the point at which a person begins trying to go to sleep or allowing him/herself to go to sleep and sleep inception time.
Sleep period/sleeping time, sometimes referred to as 'sleep'	Period between sleep inception time and awakening time, including any interim intervals of wakefulness.
Time in bed	The sum of a sleep period and the associated sleep latency period.
Polysomnography	The measurement during a subject's time in bed of his or her brain activity by means of EEG, EOG and EMG. In this report, the term EEG measurement or scanning is used. The technique involves the use of electrodes to record electrical potentials in the brain. On the basis of international standards, the data collected can be used to identify phenomena such as the stages of sleep.

Sleep EEG	Graph created using data from EEG scanning during a subject's time in bed, showing the various stages of sleep as a function of time. From such a graph, it is possible to draw conclusions regarding the structure of the subject's sleep.
Actimetry	The measurement of accelerations associated with the movement of an actimeter. In scientific research, an actimeter is a device resembling a wristwatch, which measures how much the wearer moves (by recording accelerations above a given threshold) over a predetermined time interval, typically between one second and one minute. The curve representing the amount of movement as a function of time is known as an actigram.
Measurement of stress hormones	Measurement of the quantity of (stress) hormones – typically cortisol, adrenaline (epinephrine) and noradrenaline (norepinephrine) – in the blood, urine or saliva.
Registration of wakefulness	The indication by a subject (for the benefit of an investigator) that he or she is awake, typically after waking up in the course of or at the end of his or her sleep period, by pressing a button or performing some other conscious act.
Acute phenomena	
Heart rate acceleration	A temporary rise in heart rate relative to the average heart rate assessed shortly before a noise event.
Change in the quantity of a stress hormone	The difference in the quantity of a stress hormone in blood, urine or saliva samples collected at two successive points in time.
Sleep stage change (from deeper to less deep sleep)	Change from a deeper stage of sleep to a less deep stage, as determined by a sleep EEG.
EEG awakening	Transition from a state of sleep to a state of consciousness, as determined by a sleep EEG.
Motility	The presence of movement in a short time interval, as recorded on an actigram.
Motility onset	The presence of movement in a short time interval, following an interval without movement.
Subject-registered awakening (behavioural awakening)	Awakening that is registered by the subject by means of a conscious action.
Phenomena relating to one or more sleep periods or sleep latency periods	
Average sleep latency period	The average length of the sleep latency period on a number of occasions.
Average heart rate	The average speed at which the heart beats when asleep.
(Stress) hormone concentration	The concentration of (stress) hormone in blood, urine or saliva collected during and/or after a sleep period.
Duration of a sleep stage	The number of minutes that a sleeping person is in a particular stage of sleep.
Sleep fragmentation	Within a sleep period, the frequency and duration of intervals of wakefulness recorded on a sleep EEG or intervals of motility recorded on an actigram.
Average motility/motor unrest	Within a sleep period, the recorded number of intervals involving motility divided by the total number of intervals making up the sleep period.
Average motility onset frequency	Within a sleep period, the recorded number of intervals in which motility begins, divided by the total number of intervals making up the sleep period.
Perceived quality of sleep	The quality of sleep, as perceived by a subject and described in a questionnaire response or journal entry.
Sleeping problems: difficulty falling or staying asleep	Difficulty falling or staying asleep, as perceived by a subject and described in a questionnaire response or journal entry.

Sleep disturbance	Disturbance of sleep by night-time noise, as perceived by a subject and described in a questionnaire response or journal entry.
Health problems	Problems with health, as perceived by a subject and described in a questionnaire response or journal entry
Insomnia	Sleeping disorder consistent with an internationally accepted definition, which takes account of difficulty falling or staying asleep, the daytime implications and the duration of the problems.
Raised blood pressure/hypertension	A condition characterised by systolic blood pressure higher than 160 mmHg and/or diastolic blood pressure higher than 100 mmHg (internationally recognised definition).
Noise exposure indexes	
Sound pressure level at a given point in time	The intensity of a noise at a given point in time, expressed in dB(A) (A-curve decibels).
LAmax	Maximum outdoor sound pressure level associated with an individual noise event.
LAmax_i	Maximum indoor sound pressure level associated with an individual noise event.
Equivalent sound pressure level over a given time interval *T*: *LAeq,T*	Exposure to noise for the duration of a given time interval *T* (a twenty-four hour period, a night, a day, an evening) is expressed as an equivalent sound pressure level (measured in dB(A)) over the interval in question. The equivalent sound pressure level is an 'exponential average' of the sound pressure levels occurring during the interval in question, i.e. an 'average' calculated by a method that attributes greater weight to higher sound pressure levels.
SEL (sound exposure level)	Equivalent outdoor sound pressure level associated with an individual noise event, with the equivalent level standardised at one second.
SEL_i[a]	Equivalent indoor sound pressure level associated with an individual noise event, with the equivalent level standardised at one second.
Lnight	Equivalent outdoor sound pressure level associated with a particular type of noise source between 11pm and 7am, calculated over a period of a year.
Lnight_i	Equivalent indoor sound pressure level associated with a particular type of noise source between 11pm and 7am, calculated over a period of a year. *Lnight_i* equals *Lnight* minus a sound attenuation value specific to the fabric of the individual building and the particular type of noise source.
Lden (d: day, e: evening, n: night)	Equivalent outdoor sound pressure level attributable to a particular type of noise source, over a twenty-four-hour period, adjusted using evening and night factors, calculated on an annual basis.
Li	Equivalent sound pressure level representative of exposure to a particular type of noise source, occurring in an individual's bedroom while he or she is asleep.
I_{lu} and $I_{lu;k}$	Indexes of the attenuation of airborne noise by a screening surface (wall, floor, ceiling) between dwellings; $I_{lu;k}$ is based upon a reception room of standardised dimensions.
I_{co}	Index of the attenuation of contact noise by a screening surface (wall, floor, ceiling) between dwellings.

[a] If a noise event lasts for one second, the *SEL_i* for the event is the equivalent noise level during that second (*LAeq,1s*). If a noise event lasts for a hundred seconds, the *SEL_i* for the event is the equivalent noise level during those hundred seconds: (*LAeq,100s*) plus 10*lg100 = *LAeq,100s* + 20. A constant-level noise event that lasts for a hundred seconds therefore has an *SEL_i* that is 20 dB(A) higher than the *SEL_i* of a noise event of the same constant level that lasts for one second.

Chapter 1

Noise, sleep and health

1.1 Background

People cannot function without sleep. It is therefore understandable that any disturbance of sleep by environmental factors, in particular noise, should be a cause for concern. Since it is not always easy to reduce sleep-disturbing noise, which is frequently associated with activities that are of value to the community at large, such as travel and transport, a debate has arisen regarding the health implications of sleep disturbance by environmental noise. It is undeniably the case that noise tends to disturb sleep[1,2]. However, the precise significance of such disturbance for perceived health and the development of illness is less clear[1].

Like other countries, the Netherlands has legal controls designed to limit public exposure to environmental noise, primarily with a view to managing the associated annoyance. Most of the limits that exist are concerned with exposure over a complete twenty-four-hour period and do not therefore focus specifically on the period during which most people sleep. In the Netherlands, special rules covering night-time noise are applied only in relation to scheduled overnight aircraft movements. However, legislation is presently being prepared at the EU level that does seek ultimately to reduce night-time exposure. In due course, Dutch law will be brought into line with the new EU legislation.

1.2 Ministerial commission and establishment of the Committee

Against this background, the State Secretary for Housing, Spatial Planning and the Environment wrote to the Health Council on 3 February 2003, asking that an advisory report should be prepared on the effects of night-time noise on sleep and health (see Annex A). Specifically, the State Secretary asked the Council to address the following questions:

a What are the effects (expressed in quantitative terms as far as possible) of exposure to noise when sleeping?

b How do such effects compare with other effects on health, in terms of seriousness and magnitude?

c Is it necessary to take special account of any population groups that are at particular risk?

d In view of the effects referred to, would it be advisable to introduce special rules, similar to those contained in Directive 2002/49 and the Aviation Act, for night-time noise from sources other than air traffic?

e If so, is it sufficient for such rules to be based on *Lnight*, or are additional indexes of exposure required, with a view to regulating impulse-like noises and situations involving relatively infrequent but high-intensity noise events?

f Could the public be protected by the use of a. performance-related or design requirements for residential buildings, b. personal protective gear, c. rules regarding sound pressure levels outside buildings, d. rules relating to vehicles and machinery, or e. a combination of these measures?

In response, the President of Health Council established the Committee on Sleep, Health and Noise, referred to below simply as the Committee. The members of the Committee are listed in Annex B.

1.3 Methodology

Over the last few decades, the Health Council has produced several advisory reports relating, at least in part, to the influence on sleep of exposure to noise[1,2,6-8]. The present report builds upon these earlier publications and updates their findings where justified by the subsequent emergence of further scientific information.

To support the Committee's deliberations, the secretary produced a summary of available information concerning the interrelationships between noise, sleep and health. This involved carrying out a number of literature searches. The file of relevant literature was complemented by pertinent data supplied by members of the Committee.

In addition, interested parties were invited – both in direct correspondence and in an advertisement placed in the *Government Gazette* of 22 July 2003 – to submit any information that they felt might be helpful to the Committee. The bodies and individuals that responded to this invitation are listed in Annex C.

On 2 July 2003, the Committee organised an international workshop, which was attended by experts from the Netherlands and other countries. The workshop formed part of the *8th International Congress on Noise as a Public Health Problem* (ICBEN2003), which took place between 30 June and 3 July 2003 at *De Doelen* in Rotterdam. The Committee drew upon the information obtained at the workshop when preparing this report.

The Committee finalised the text of this report in the course of six meetings.

1.4 The collation of available scientific data

Relevant publications and reports were collected by several means:

- A search of the document library at TNO Inro's Department of Health and Environment was carried out for material relating to sleep and the influence of noise on sleep. A collection of relevant documentation was compiled in connection with preparation of the 1994 advisory report *Noise and Health*[2], and efforts have been made to keep the collection up to date over the intervening decade. In addition, reports on international (acoustic) conferences were screened for publications on the effect of noise on sleep.
- The library staff at the Health Council carried out searches of *Medline*, *Biosis*, *Embase* and *PsychInfo* for relevant documents published since 1994. These searches were performed using combinations of the keywords 'noise', 'sleep' and 'effect', with the latter linked to numerous parameters. Some of the effect parameters used were as listed in the first columns of Tables 12, 13 and 14*. Searches were also carried out using the effect variable specifications** referred to. Information about sleep disorders was sought by the Committee secretary using the keywords 'insomnia', 'prevalence' and 'sleep apnoea', 'prevalence' and 'narcolepsy', and 'prevalence' and 'restless legs syndrome'. Searches were also carried out using the names of a number of researchers known to be active in the field of noise-related sleep disturbance.
- Individual members of the Committee supplied literature concerning their specialist fields.

* The direction of the change in a given effect parameter was not specified. So, for example, searches were made on 'sleep stage', not on transition from a deeper stage of sleep to a less deep stage.

** So, for example, in addition to searching on 'stress hormone', searches were carried out using the terms 'adrenaline', 'noradrenaline' and 'cortisol'.

1.5 Structure of the report

The structure of this advisory report is as follows. Chapter 2 outlines the terminology used. Chapter 3 summarises the results of research into the effects of exposure to night-time noise when sleeping. Next, a number of acoustic issues are considered in chapter 4. In chapter 5, the Committee directly addresses the six questions posed by the State Secretary. The main body of the report concludes with a list of references.

Appendices A, B, and C set out, respectively, the content of the State Secretary's letter, the composition of the Committee, and the names of bodies and individuals who responded to the invitation to submit information for consideration by the Committee. Annex D contains a discussion of research into consequences of exposure to night-time noise when sleeping. Annex E describes the situation with regard to sleep disorders and sleeping problems in the population at large, and Annex F summarises the most recent Health Council advisory report on environmental noise (*Assessing Noise Exposure for Public Health Purposes*)[8]. Annex G reproduces the text of an attachment to a letter from the RIVM containing recent information on the noise exposure in the Netherlands.

Chapter 2

Central concepts

In this chapter, the Committee begins by presenting a summary of the different types of environmental noise (2.1). Section 2.2 explains the indexes used in this report to characterise exposure to noise, while section 2.3 is devoted to various aspects of sleep. In section 2.4, a model is presented that describes the influence of environmental factors on health and well-being. Finally, an assessment of the evidence for the effects of nighttime noise is made in section 2.5.

2.1 Research into the relationship between environmental noise and sleep and health

Environmental noise can be divided into a number of types on the basis of source:

- Traffic sources: aviation, road traffic, rail traffic and shipping
- Stationary environmental sources, such as factories, shooting ranges, shunting yards, wind turbines, climate control systems, (temporary) building and demolition sites
- People and human activities in the neighbourhood not covered by the first two categories (neighbourhood noise)
- People and human activities in adjacent dwellings (noise from neighbours)

Research into exposure to environmental noise may be divided into two broad types:

- Research into the prevalence of the effects of exposure to environmental noise (inventory research)

- Research into the relationship between exposure and the extent to which an effect occurs: epidemiological research with population groups and laboratory research with human subjects.

A nationwide Dutch inventory study was undertaken in 1998, in the context of which four thousand people aged sixteen and above completed questionnaires[9]. This study indicated that passenger cars, lorries and mopeds were the types of vehicle most often associated with sleep disturbance in the Netherlands (being mentioned as causes of disturbance by 7, 6, and 10 per cent of respondents, respectively). Sleep disturbance is (much) less frequently associated with noise from aviation or rail traffic, or from factories and other economic activities. Where noise from neighbours is concerned, the most frequently mentioned problems were contact noise (people going up stairs, slamming doors, etc) and noise from audio equipment, being referred to by 8 and 6 per cent of respondents, respectively. Neighbourhood noises also proved to be a significant cause of sleep disturbance, mentioned by 8 per cent of respondents. See Figure 1; further details are presented in Table 21 in Annex D.

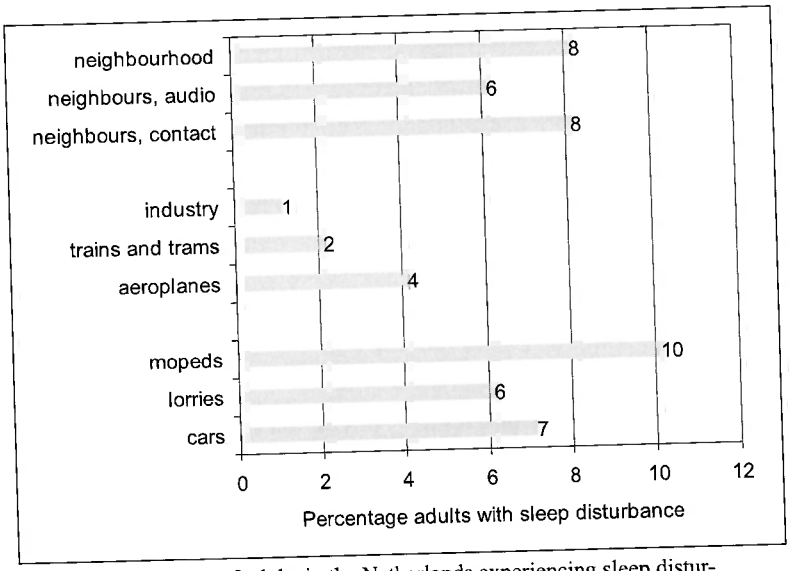


Figure 1 Percentage of adults in the Netherlands experiencing sleep disturbance due to particular noise sources in the residential environment[9]. The national inventory study carried out in 1998 asked respondents to indicate the extent to which their sleep was disturbed by noise from various sources, by giving a number between 0 and 10, where 0 = not disturbed at all and 10 = very highly disturbed. A standardised method was then used to calculate the percentage of respondents reporting sleep disturbance and high sleep disturbance. This involved transforming the 11-point scale into a continuous scale from 0 to 100. Respondents who scored 50 or more on this scale were deemed to suffer from sleep disturbance.

Most of the epidemiological and laboratory research that has been conducted into the relationship between, on the one hand, sleep and health characteristics and, on the other, exposure to night-time noise has focused on *noise from traffic sources* (other than shipping). Epidemiological research into the influence of *stationary environmental sources*, such as industrial premises, has been confined to self-reported noise-related annoyance over a twenty-four-hour period. However, there have also been some isolated laboratory studies that have looked at the effect of specific noise characteristics that can be associated with stationary environmental sources, such as a very rapid rise in intensity at the start of a noise event. The Health Council published a report on this topic in 1997[8]. The way in which the specific characteristics of environmental noise help to determine its effect is briefly explained in Annex F. The Committee returns to this matter in chapter 4, and in its answers to the State Secretary's questions.

Noise from neighbours comes in many different forms. Furthermore, research has shown that the factors which determine whether people are disturbed in their sleep by such noise are both numerous and very varied. As a result, it is not possible to determine the relationship between exposure to noise from such sources and the degree of sleep disturbance. However, in this report, the Committee does comment on the influence of features designed to attenuate noise transmitted between dwellings and on certain matters relating to the disturbance of sleep by noise from neighbours.

So far as the Committee has been able to ascertain, no research has been done into a possible link between exposure to *neighbourhood noise* and sleep disturbance. The Committee has therefore been obliged to disregard this topic.

To sum up, therefore, the nature of the scientific data research available is such that this advisory report necessarily concentrates on the consequences of night-time traffic noise (from sources other than shipping) on sleep and health characteristics.

2.2 Characterisation of exposure to night-time noise

The characteristics of a noise include its intensity and its pitch. The louder a noise is, the greater its intensity. The *intensity* of a noise is expressed in decibels (dB). *Pitch* is an expression of acoustic frequency: a buzzing noise is a low-pitch sound, while a hissing noise is a high-pitch sound. Most environmental noises have both high-pitch and low-pitch components. However, the ear is not equally sensitive to all such components. Consequently, when measuring the intensity of an environmental noise, a filter is normally used to reflect the range of human perception. The most widely used filter is known as the 'A filter', for the determination of a *sound pressure level* in dB(A). The 'A' in 'dB(A)' indicates that the figure is adjusted by an internationally standardised method to reflect the relative sensitivity of the ear to low-frequency and high-frequency

components ('A-weighting'). Another commonly used filter is the C filter; the main difference between the A filter and the C filter is that the latter allows through more low-frequency sound than the former.

The sound produced by most sources of environmental noise does not remain at a constant level over time. The noise from an aeroplane or train, for example, consists of a number of temporally distinct passages (noise events). By contrast, the noise from a motorway, when heard from a distance, is more of a constant drone. Exposure to constant or fluctuating noise for a given time interval (e.g. a twenty-four-hour period, night, day or evening) is expressed as an *equivalent sound pressure level* (in dB(A)) for the interval in question. An equivalent sound pressure level is a sort of average of the sound pressure levels occurring during the relevant time interval. However, it is not a true arithmetical average, since more weight is given to higher sound pressure levels than to lower sound pressure levels. Equivalent sound pressure levels for particular parts of the twenty-four-hour period are used as indexes of exposure both in research and for regulatory purposes.

The indexes used to characterise noise in this advisory report (as previously listed in Table 1) are briefly discussed below.

The *intensity of a noise event, as perceived in the bedroom* is characterised by *LAmax_i* and *SEL_i* (*i* stands for *indoor*). *LAmax_i* is the maximum sound pressure level during a noise event, while *SEL_i* is the equivalent sound pressure level of a noise event for a standardised one-second period. The *LAmax_i* and *SEL_i* for a given type of noise source are often closely related, as are the *LAmax* and *SEL*; so, for example, the correlation for indoor values of aviation noise was found to be 0.94 and that for outdoor values of lorry noise to be 0.99[10-13].

The long-term outdoor night-time noise exposure at a particular location associated with a particular noise source is characterised using *Lnight*, the annual equivalent sound pressure level between 11pm and 7am attributable to that source. Within the EU, *Lnight* is designated as the index of the night-time noise exposure attributable to a given noise source that should be used for certain purposes[3,4].

The *long-term night-time noise exposure in dwellings* can be characterised using *Lnight_i*. This index of equivalent sound pressure level is calculated by deducting from *Lnight* the average attenuation provided by the fabric of the walls. The Building Decree lays down requirements regarding the noise-attenuating properties of the walls of dwellings and other noise-sensitive buildings. The attenuation provided by the wall of a new building has to be at least 20 dB(A)[14].

The *long-term outdoor noise exposure at a particular site, as associated with a given noise source* is characterised with *Lden*, the annual equivalent sound pressure

level over a twenty-four-hour period. In the calculation of this figure, the equivalent sound pressure levels during the evening (7pm to 11pm) and the night (11pm to 7am) are increased by 5 and 10 dB(A), respectively. *Lden* is used in EU directives as an index of noise exposure over a twenty-four-hour period[3,4].

Li is an expression of the *personal noise exposure when sleeping associated with a given noise source*. It is an index of the equivalent sound pressure level in an individual's bedroom during the sleep period, as attributable to a given noise source over an extended period of time. It therefore expresses the individual's noise exposure when sleeping, taking account of the length of his or her sleep period, the time he or she goes to sleep and gets up, the outdoor noise exposure and the difference between the individual outdoor and indoor noise exposure. Calculation of the latter difference also takes account of whether the person in question has his or her bedroom window open or closed. Hence, while the *Lnight_i* for a given noise source may be constant throughout a particular part of a residential site, the *Li* values for the individual residents may differ significantly, due to behavioural differences or variations in the properties of the dwellings.

Sound attenuation between dwellings can be quantified using an index for the attenuation of airborne noise, I_{lu}, while $I_{lu;k}$ is a similar index which also takes account of the volume of the reception room and the area of the common screening structure, given its characteristic sound attenuation properties. A screen's ability to attenuate contact noise transmitted between two dwellings is quantified using the index for contact noise, I_{co}[14].

To give an impression of the environmental noise situation in the Netherlands, Figure 2 shows the distribution of the traffic-related outdoor noise exposure (*Lden, Lnight)* on dwellings in the year 2000, broken down by source category (motorway traffic, provincial road traffic, municipal road traffic, rail traffic and air traffic)[15]. From the graphs, it will be very clear that municipal road traffic generates the most noise, both at night and over a twenty-four-hour period.

To give another example, 40 dB(A) is a widely used limit for twenty-four-hour noise exposure (equivalent sound pressure level) in Dutch nature reserves and recreational areas. In the Central Veluwe Nature Reserve, the noise exposure (twenty-four-hour equivalent sound pressure level) associated with motorway traffic, provincial road traffic, rail traffic and air traffic accounts for, respectively, 19, 12, 6, and 0 per cent of all environmental noise in areas where this limit is exceeded[16]. Across the reserve as a whole, the average equivalent sound pressure level associated with all noise sources together is 53 dB(A); across areas where cycling is possible, the corresponding figure is 57 dB(A) and across areas where walking is possible, it is 52 dB(A).

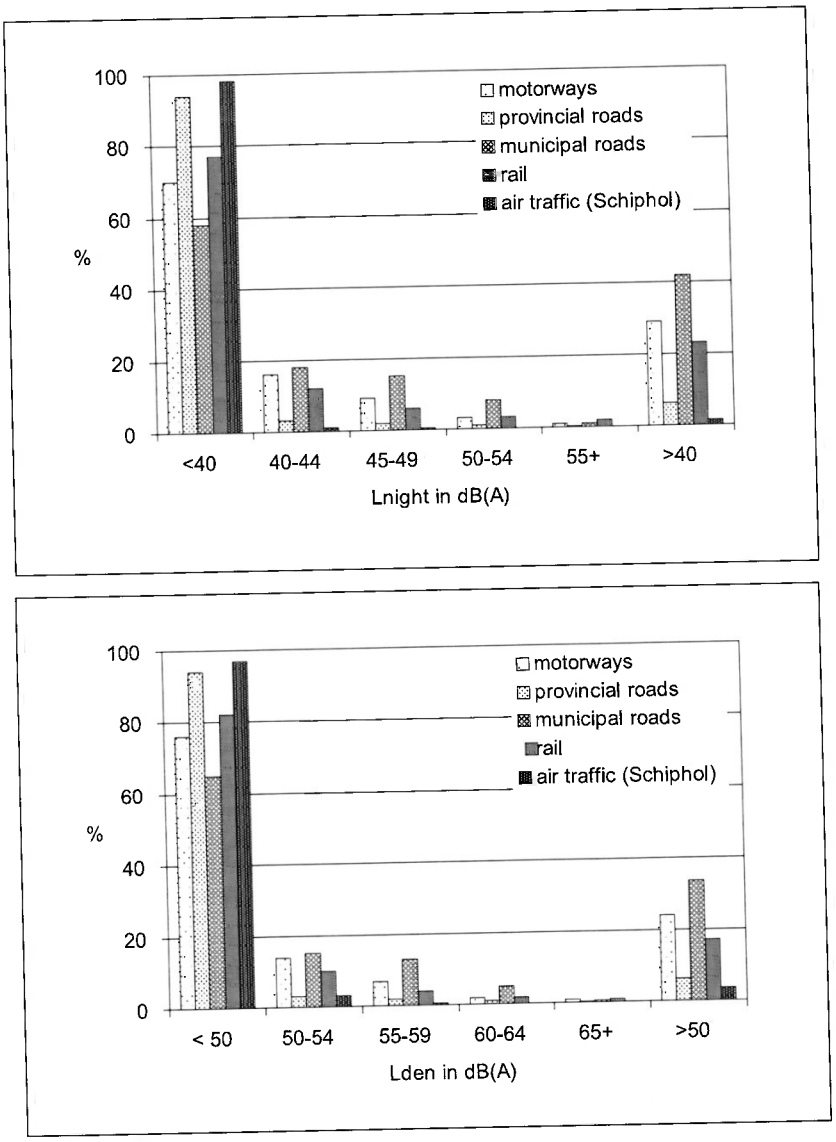


Figure 2 The distribution of traffic-related outdoor noise exposure (*Lnight* in the top graph, *Lden* in the bottom graph) on dwellings in the Netherlands in the year 2000, broken down by source category (motorway traffic, provincial road traffic, municipal road traffic, rail traffic and air traffic)[15].

2.3 Sleep

2.3.1 *What is sleep*?*

In the background study document[17] for the Health Council's 1991 report *Aviation Noise and Sleep*, Hofman – following the textbook *Principles and Practice of Sleep Medicine*[18] – described sleep as a periodically occurring state of apparent inactivity, in which the organism's responses to environmental stimuli are modified to an extent which is not uniform for all stimuli and which differs from one individual to another. Sleep should not be regarded as the mere absence of consciousness, but as a cyclical, active neurophysiological process[6].

By sleeping, people recover physically and mentally from their efforts. In addition, they process the information that they have absorbed during the day. Finally, sleeping is also enjoyable[19].

Human beings have an internal biological clock with a cycle of roughly twenty-four hours (the circadian rhythm: *circa* = approximately, *dies* = day). Sleep is also a cyclical phenomenon: in adults, it generally consists of roughly five periods of approximately 90 minutes, in each of which there is a spell of so-called 'REM sleep' (or 'dreaming sleep'; REM stands for *rapid eye movement*) and a spell of non-REM sleep. Non-REM sleep is itself divided into four stages, discernible from distinctive electroencephalogram (EEG) patterns. Stages 1 and 2 are referred to more generally as light sleep and stages 3 and 4 as deep or SWS sleep (SWS stands for *slow wave sleep*, a phrase that refers to the extended delta waves that characterise deep sleep on an EEG). When a person is awake, his or her EEG is characterised by so-called alpha and beta waves. Deep sleep tends to occur more towards the start of a period of sleep and REM more towards the end. As one gets older, the amount of deep sleep one needs declines. Waking up from time to time in the course of a period of sleep is part of a normal sleeping pattern[18]. Such waking periods may be brief or may last some while. 'EEG awakenings' of short duration, lasting between three and fifteen seconds, are referred to as *(cortical) arousals*.

It is generally believed that deep sleep and REM sleep are the most important sleep components, and that stages 1 and 2 are transitional stages. Both deep sleep and REM sleep are necessary for the processing of information taken in during the period prior to sleeping[20-31].

When one is asleep, changes also occur in one's hormone balance.

* See table 1 for explanations of the terms used.

2.3.2 *What is normal sleep?*

The term 'normal sleep' is defined in various ways in the published literature, by reference to both objective and subjective criteria. The objective criteria used include sleep duration, the length of time taken to fall asleep (sleep latency period), sleep efficiency (the time that one spends asleep as a percentage of the time one spends in bed), and the number of EEG awakenings, including cortical arousals. As well as being generally age-related and sometimes gender-related, these sleep characteristics vary substantially from one individual to the next. The subjective criteria used to define normal sleep are based on self-reported sleep characteristics, such as satisfaction with one's sleep, the feeling of being well-rested when one wakes up, and alertness during the day. As long as the values for all three characteristics are within a given range, the subject's sleep may be regarded as 'normal'.

People without sleep disorders who are not while sleeping exposed to loud noises (whether environmental noise, noise from inside their own dwellings or neighbouring dwellings) typically report waking up (subject-registered, behavioural awakening) one and a half to two times during an average sleep period, not counting the occasion that they wake up prior getting up[52]. The number of EEG awakenings, including cortical arousals, averages ten to twelve per night (although there is considerable individual variation)[52] Such events are therefore approximately six to seven times more frequent than spontaneous subject-registered awakenings. The general figures of one and a half to two subject-registered awakenings per night and ten to twelve EEG awakenings per night can be seen as defining the range of spontaneous awakening frequencies in a population unaffected by sleep disorders or sleep disturbance.

2.3.3 *Sleep and quality of life*

The phrase 'quality of life' is used to mean various things, three of which are taken into account here. First, 'quality of life' can refer to satisfaction with one's health: health-related quality of life. The phrase can sometimes also be an expression of satisfaction with life in general. In the latter sense, 'quality of life' is synonymous with 'happiness'. The third relevant meaning of the phrase is satisfaction with the environment in which one lives. It is in this third sense that 'quality of life' is most often used by researchers concerned with the annoyance caused by night-time noise. Nevertheless, in the Netherlands in particular, more attention has in recent years been given to quality of life in the first sense[32-35].

In order to measure any diminution of *health-related quality of life* associated with a given cause, such as night-time noise, one first has to specify the nature of the health

diminution. Where health diminution is detected (or assumed), an assessment of the subject's quality of life ('satisfaction'), in the form of a weighting factor, can be linked to the diminished state of health. In this way, diminution in health-related quality of life can be determined in quantitative terms. One expression of such diminution is Murray's DALY (*Disability Adjusted Life Year*)[36].

Diminished satisfaction with the environment in which one lives can be determined relatively easily by obtaining information from the subject using a questionnaire.

As a 'condition', sleep is also seen as a component of health. Thus, if a person is not sleeping well, the direct consequences – fretful waking periods in the night, tiredness the next day and the real or supposed impact of tiredness on daytime activities – lead to a diminution of his or her health-related quality of life. Such diminution can be substantial, as illustrated by the quality-of-life weighting system developed by Stolk *et al*[37]. Insomnia, as diagnosed by a GP, has a quality-of-life weighting of 0.83, compared with 0.93 for a spastic colon and 0.68 for localised lumbar pain.

The sleep disorders – particularly insomnia – and sleeping problems prevalent in the population at large are reviewed in Annex E. Following the examination of the influence that night-time noise has on sleep, the Committee considers whether there may be correspondences between, on the one hand, certain sleep disorders and sleeping problems in the population at large and, on the other, noise-related sleep disturbance and, if so, whether certain conclusions may reasonably be drawn concerning the influence of noise on sleep.

2.4 Environment and health

In several recent reports, the Health Council has presented its view of the relationship between environmental factors and health[1,38]. Figure 3 is a schematic illustration of the way that factors in the environment exert an influence and thus can have implications for human health and well-being. The use of the phrase 'health and well-being' in this context is indicative of the fact that, in considering the relationship between environmental factors and health, account is taken of subjective perceptions of health[39].

People are not passive under the influence of environmental factors. External influences trigger responses designed to modify their effects and, insofar as the influences are harmful, to counter them or compensate for them. Environmental factors will therefore always have an effect on a person, which is demonstrable in many cases. However, such effects do not necessarily have negative long-term implications for health and well-being.

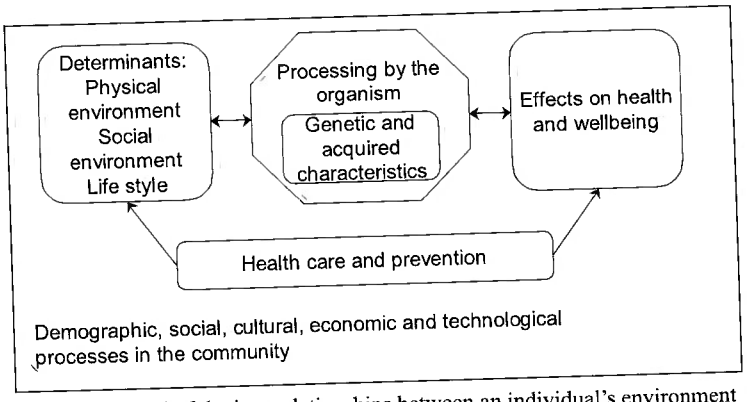


Figure 3 Model of the interrelationships between an individual's environment and his or her health and well-being (from earlier Health Council reports[1,38]).

The way an individual responds to external factors depends on a combination of inherent and acquired characteristics. Consequently, the effects of such factors and their implications for the health and well-being of the individual differ from person to person. A given potentially harmful influence may be tolerated by one person, but may adversely affect the health and well-being of another. Furthermore, the effect that an environmental factor has can be influenced by the extent to which other factors are simultaneously at work.

2.4.1 *Cause-effect chain*

The study of links between environmental factors and health generally involves following cause-effect chains[40] (see Figure 4).

At the point of progression from each block to the next, two questions have to be addressed:

- Is there a causal relationship: is the next event a consequence of the last?
- What influence do other factors have?

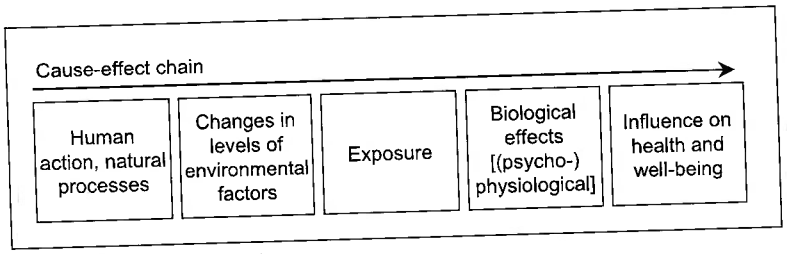


Figure 4 Cause-effect chain.

The 'exposure' block plays a special role. It may be regarded as a 'filter', which under certain circumstances connects the first two blocks to the last two. In line with the model shown in Figure 4, exposure leads to what are described in the diagram as 'biological' effects: physiological and psycho-physiological responses by the individual. These responses are sometimes predictors of brief or prolonged declines in the individual's health and well-being.

2.5 Assessment of the effects of night-time noise

For an assessment of the relationship between exposure to night-time noise when sleeping and effects on an individual's health and well-being, the Committee considers the following to be of particular importance:

- The distinction between biological effects and health effect (see Figure 4)
- The 'significance' of a health effect
- The exposure-effect process
- The strength of the evidence for each relationship.

These four topics are considered in more detail below.

2.5.1 *The distinction between biological effects and health effects*

In the model illustrated in Figure 3, environmental noise triggers biological responses from the individual because, even when sleeping, he or she still needs to assess and process 'stimuli' from the environment. The biological responses that are liable to occur include waking up, difficulties getting off to sleep and increased motor unrest while sleeping. To some extent, these responses involve acute changes during exposure to a noise, and to some extent they involve changes that manifest themselves over a night (before, while and after sleeping). In research, such effects are often used as markers of change in an individual's state of health and well-being. However, this makes it necessary to consider whether a given biological effect is in fact a predictor of long-term decline in health and well-being, which may or may not depend upon the nature and duration of the exposure. To this end, the Committee distinguishes between biological effects and effects on an individual's health and well-being. The former manifest themselves at the time of exposure and in the course of a sleep period, while the latter become apparent only in the longer term.

2.5.2 *The significance of a health effect*

The 'significance' of a health effect is a concept that includes the seriousness of the effect. The Committee has grouped the relevant effect parameters under five headings: quality of sleep; general well-being; social contacts and concentration; medical conditions; reduction in life expectancy.

2.5.3 *The exposure-effect process*

Not all levels of night-time noise have an effect. It is therefore desirable to be familiar with the exposure process that is liable to induce an effect. The Health Council's 1994[2] report on the consequences of exposure to noise introduced the term 'observation threshold' for use in this context. This term is defined as follows:

> The lowest level of exposure at which epidemiological research has shown noise typically has an effect on health. Where an exposure-effect function has been calculated for a given effect (...) the observation threshold will be obtained from that function.

In the current report, the term 'observation threshold' is also applied to effects that are not *necessarily* health effects. In most cases, epidemiological research with human subjects has found that effects occur only when exposure exceeds a certain level. It is possible that effects also occur – in some people, at least – at lower levels, but this possibility is usually not easy to investigate in practice.

2.5.4 *Strength of the evidence*

In order to define the degree of certainty concerning the relationship between exposure to night-time noise and a particular effect, it is normally necessary for a researcher to describe his/her findings in detail, since this is the only way to give a proper account of what is and is not known. However, when preparing a report for policy support purposes, it is desirable to indicate the degree of (un)certainty using a simple scale. The Committee has accordingly introduced a simple uncertainty scale, based on those developed by IARC[41] and a research team in Jülich, Germany[42].

Since this advisory report draws mainly on *epidemiological* research into the influence that night-time noise has on people's sleep, supplemented by a small number of laboratory studies, assessment of the strength of the evidence concerning a given relationship here involves determining the extent to which there is a statistically significant correlation between exposure and effect, so that a conclusion may be drawn concerning

causation by applying the so-called 'Hill criteria'[43] (about which more will be said later) and taking account of any other relevant considerations.

In line with the position taken by the IARC and the findings of the 1994 advisory report *Noise and health*, the following definitions have been adopted for the three categories of evidence.

Table 2 The strength of evidence concerning a relationship: definitions of the three levels.

Sufficient	A causal relationship has been demonstrated between exposure to night-time noise during the sleep period and a given effect. A relationship has been observed between exposure and effect in research which may reasonably be deemed to exclude the possibility of coincidence, bias and distortion, and it is plausible that the effect is attributable, at least in part, to the exposure.
Limited	A relationship between exposure and effect has been observed, and a causal relationship is credible, but the possibility of coincidence, bias or distortion cannot confidently be excluded. The presence of a relationship is generally plausible.
	No direct link has been established between exposure and effect, but there is good quality indirect empirical evidence for such a link, and the presence of a link is plausible. Indirect evidence may be said to exist if it has been observed that exposure has an intermediary effect, which is known from other research to lead to the ultimate effect under consideration.
Insufficient	The underlying research lacks the quality, consistency or weight necessary to support a conclusion regarding the existence of a causal relationship between exposure and effect. A link is not particularly plausible or is implausible.

The definitions given in Table 2 incorporate those developed by the IARC, but additionally make reference to the plausibility of a relationship. Hence, for the evidence of a relationship to be classed as 'sufficient', it is necessary for the causal link to be plausible. Otherwise, the evidence is classed as 'insufficient'. Furthermore, a subcategory of limited evidence not recognised by the IARC has been added: there is deemed to be limited evidence of a relationship where there is indirect empirical evidence that exposure has an intermediate effect, which is known from other research to lead to the ultimate effect under consideration. Inclusion of a relationship within this category depends on examination of its plausibility, with particular emphasis on the differences and similarities in nature and seriousness of the intermediate effect in each case (see Figure 5).

Hill criteria for assessing degree of certainty

When assessing epidemiological research findings to determine whether there is evidence of a causal relationship between exposure and effect, use is often made of the so-called Hill criteria[43]. In a speech to the *Section on Occupational Medicine* of the *Royal*

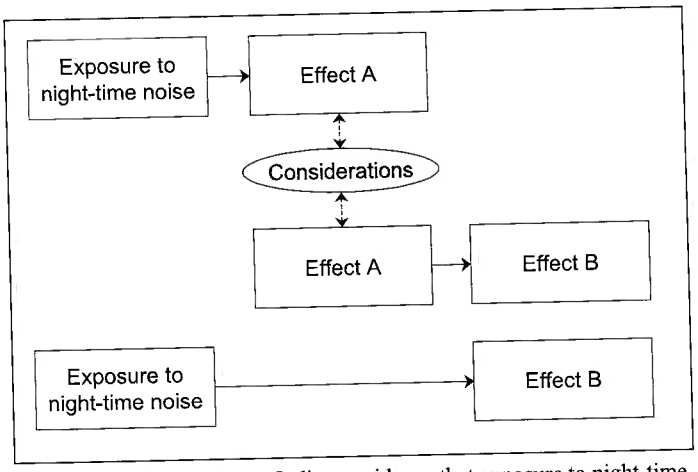


Figure 5 Indirect evidence. Indirect evidence that exposure to night-time noise has an effect (effect B). There is sufficient evidence for a link between exposure to night-time noise and effect A, and there is sufficient evidence that effect A leads to effect B in the general population. Furthermore, it is plausible that noise-induced effect A is consistent with effect A in the general population. Hence, there is limited evidence of a link between exposure to night-time noise and effect B.

Society for Medicine, the section chairman, Professor Austin Bradford Hill, put forward the following criteria for establishing an argument of causation:

- Strength of the relationship
- Consistency
- Specificity
- Temporal sequence
- Biological gradient
- Biological rationale
- Coherence
- Experimental evidence
- Analogous evidence.

Hill pointed out that it was not possible to provide absolute rules for the application of his criteria. What was required was careful assessment of the data, using the criteria for guidance. In practice, decisive criteria tend to be 'consistency', 'biological rationale', 'strength of the relationship' and 'biological gradient'[44].

Hill also said that statistical significance was of secondary importance, except insofar as a significance test served to remind the assessor that a study's observations might have been the product of mere chance. In recent years, meta-analytical methods have been developed to enable conclusions to be drawn by examining a number of studies

collectively. However, whether the application of such methods can ever substitute for careful, well-informed analysis is open to question[45].

Irrespective of the merits of meta-analysis for the extraction of evidence, the Committee does not believe that the available research data lends itself to quantitative meta-analysis with a view to reaching conclusions regarding the relationship between exposure to noise during the sleep period and (ultimate) effects on health and well-being. What is necessary is to reach consensus regarding the significance of the research findings, in which context the Hill criteria can, as indicated above, play a useful role.

Chapter 3

Effects of exposure to noise when sleeping

In sections 3.1 to 3.4, the Committee presents a survey of the effects of exposure to noise when sleeping, and draws a number of conclusions regarding the correlations between, on the one hand, certain sleep disorders and sleeping problems in the population at large and, on the other, the consequences of noise-related sleep disturbance. In Section 3.5, an estimate is made of the prevalence of some of the consequences of exposure to night-time noise for health and well-being and the associated disease burden in the Dutch population.

3.1 Laboratory and field research

In the following discussion of the available research data on the effects of exposure to noise when sleeping, the Committee concentrates on the findings of field research. The reason being that laboratory research does not always take proper account of the habituation to noise that tends to take place in practice. (Although it was, in fact, laboratory research that first demonstrated this effect twenty-five years ago (see Figure 6)[46].)

Figure 6 shows that, in the course of an experiment, the probability of EEG awakening decreases substantially, although there is barely any alteration in the probability of change from a deeper stage of sleep to a lighter stage. It may therefore be concluded that habituation does not influence all the effects of exposure to noise when sleeping to a similar extent. It should be pointed out that laboratory research has also shown that the probability of exposure to noise having a given effect can *increase* in the later nights of a study[47].

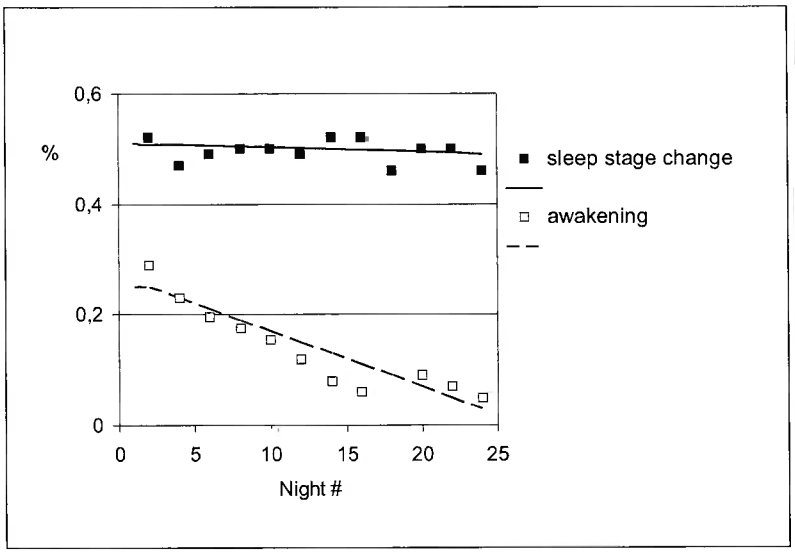


Figure 6 Average probability of the noise of a lorry with an *LAmax_i* of 65 dB(A) resulting in a change from a deeper stage of sleep to a less deep stage, or in EEG awakening, as a function of the night of exposure[46].

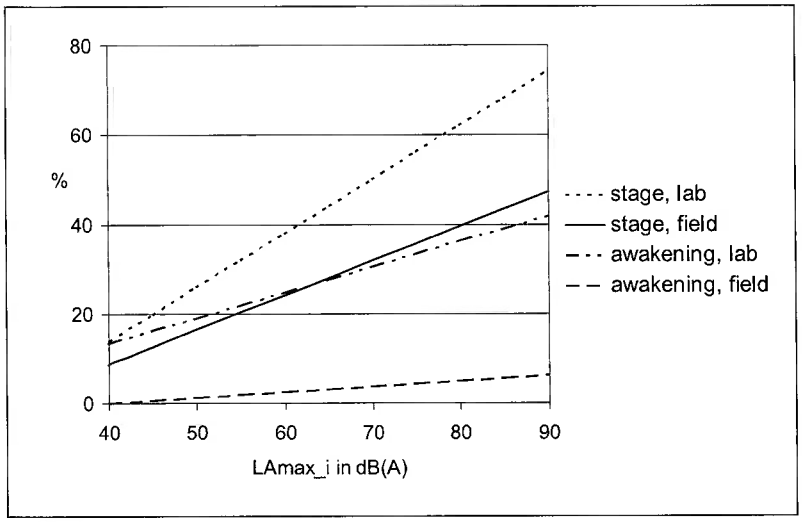


Figure 7 Average probability of sleep stage change and of EEG awakening as functions of *LAmax_i* for laboratory research subjects and for field research subjects exposed at home[48].

The fact that laboratory research sometimes sheds little light on the habituation effect is illustrated by the exposure-effect relationships reported by Pearsons *et al*[48]. The effects studied by this team were the probability of EEG awakening and the probability of change from a deeper stage of sleep to a less deep stage. Their findings, as obtained from field and laboratory research, are illustrated in Figure 7. From the figure, it will be clear that, for a given *LAmax_i*, the probability of EEG awakening or sleep stage change is much greater among laboratory subjects than among people accustomed to experiencing night-time noise at home.

Therefore, to obtain insight into the effects of noise on sleep and health, it is particularly important to carry out field research involving people who are exposed to a given noise source over a longer period of time. Mechanisms can be studied in the laboratory, but the strength of an effect observed in the laboratory is not representative of the 'real' world.

The Committee has divided the effects of exposure to night-time noise on sleep into two groups: biological effects (acute responses to noise and effects over a night (before, while and after sleeping)) and effects on health and well-being resulting from chronic exposure to noise when sleeping (for details, see Tables 12 to 14 in Annex D).

3.2 Acute biological effects

The position as described in an earlier Health Council report

In 1991, the Health Council published an advisory report on aviation noise and sleep[6]. In the associated background study document, Hofman summarised the results of laboratory and field research published up to 1991[6]. Her findings are presented in Table 3. She grouped the results of the reviewed studies into five categories: significant change in the anticipated direction (significance level: 2.5 per cent), trend in the anticipated direction, no change, trend not in the anticipated direction, significant effect not in the anticipated direction. In the table, the latter four categories are unified under the heading 'no statistically significant change in the anticipated direction'. The results relate mainly to noise from road and air traffic, although one or two of the reviewed studies were concerned with the effects of noise from rail traffic or industrial activities.

Table 3 The results of research published up to 1991 relating to acute changes induced by exposure to night-time noise events[17].

Detection method	Effect	Number of studies in which significant change was observed	Number of studies in which no significant change was observed
EEG	Prolongation of sleep latency period	17	15
	EEG awakening	38	9
	Change from a deeper stage of sleep to a less deep stage	35	20
	Transition from REM sleep to another sleep stage and change in sleep structure	27	11
ECG	Increased heart rate	16	7

3.2.1 *Comparison of five acute effects of exposure to aviation noise*

A great deal of laboratory research has been carried out into acute responses to noise. The precise temporal correlation between noise and response observed in these studies leaves no doubt that the responses in question were brought about and strengthened *by noise.*

Figure 8 illustrates the relationship between each of several acute responses to a noise event (the passage of an aeroplane) and exposure to the event in question. The relationships were determined by the Committee using data from field research into the consequences of (almost exclusive) exposure to aviation noise. The graph shows the probability of a noise-induced response in a time window of five minutes spanning the occurrence of a noise event (from approximately one minute before to four minutes after the *LAmax_i* of the noise event). Notably, most responses occurred in the interval from one minute before to one minute after the moment of maximum noise exposure (*LAmax_i*). As indicated by the graph, noise increases the probability of the following:

- Change from a deeper stage of sleep to a less deep stage, as detected by EEG (stage_EEG)
- Motility (motor unrest) in one of the ten thirty-second intervals making up the five-minute observation window (motility)
- Motility onset (onset of motor unrest) in one of the ten thirty-second intervals making up the five-minute observation window (motility_onset)
- EEG awakening (awake_EEG)

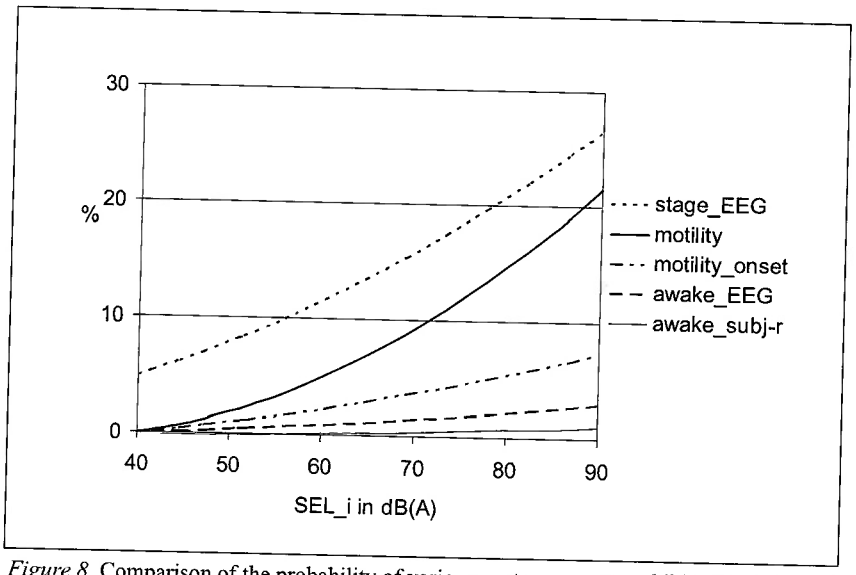


Figure 8 Comparison of the probability of various acute responses exhibited by a subject exposed to noise events while sleeping. The responses concerned are those occurring within a five-minute time interval, from one minute before to four minutes after the *LAmax_i* of the noise event. For an explanation of the response curve labels, see the main text. The relationships have been determined almost exclusively from research into aviation noise. Because of the assumptions upon which they are based, the curves for EEG awakening (awake_EEG) and sleep stage change (stage_EEG) should be regarded as, respectively, tentative and very tentative[48-53].

- Subject-registered (or behavioural) awakening (awake_subj-r). Subject-registered awakening is generally awakening that the subject registers by pressing a button. In other words, it is an event that entails the subject not only waking up, but also being aware of his/her circumstances to the extent necessary to recall that his/her wakefulness should be registered by performing the prescribed action. Subject-registered awakening therefore implies a higher level of consciousness than EEG awakening.

The relationships shown in Figure 8 are given for the range of *SEL_i* values from 40 to 90 dB(A). At night, an aeroplane passage with an *SEL_i* of 40 dB(A) is normally readily discernible indoors. An *SEL_i* of 90 dB(A) equates to a very loud noise event.

Not all the relationships illustrated in Figure 8 are equally reliable. The Committee believes that the relationships between exposure and subject-registered awakening, motility and motility onset have been defined on the basis of sound evidence. However, definition of the relationships based on EEG data (EEG awakening and sleep stage change) required an assumption, namely that the probability of noise-induced EEG awakening is 40 per cent of the probability of motility being triggered by noise[**]. However, it is not certain that this assumption is valid in the particular context of exposure to

aviation noise. Furthermore, in order to estimate the probability of a sleep stage change, the Committee has drawn upon the relationships between exposure and the probability of EEG awakening and the probability of sleep stage change illustrated in Figure 7. The Committee therefore regards the curve for EEG awakening as tentative and the curve for sleep stage change as very tentative.

From Figure 8, it is apparent that the observation threshold for the acute effects 'motility', 'motility onset', and 'EEG awakening' is an *SEL_i* of 40 dB(A) (*LAmax_i* of 32 dB(A)), while the observation threshold for subject-registered awakening is an *SEL_i* of 54 dB(A). On the basis of the tentatively plotted curves, the observation threshold for sleep stage change appears to be lower than an *SEL_i* of 40 dB(A).

3.2.2 *Extrapolation from aviation noise to road and rail traffic noise*

Figure 8 is based almost entirely on the results of research into aviation noise. Road and rail traffic noise also increase the probability of motility onset and of EEG-registered changes (EEG awakening and sleep stage change), and the observation thresholds for these noise sources are similar to those for aviation noise (see Annex D). It should be pointed out that this observation is based primarily on outdoor sound pressure level data; the use of accurate indoor data might yield a different result. In consideration of these matters, while there is insufficient evidence that road and rail traffic noise can cause subject-registered awakening, the Committee anticipates that road and rail traffic noise events are indeed capable of triggering such a response, although the threshold might not be an *SEL_i* of 54 dB(A).

3.2.3 *Motility and motility onset*

Over the last ten years, three large-scale field studies on aircraft noise have been carried out. Using data from these studies, it is possible to define the relationship between *LAmax_i* or *SEL_i* and the probability of acute motility being induced by the noise of a passing aeroplane[12,49,51]. The probability of acute motility increases as *LAmax_i* or *SEL_i* increases. From the Dutch research, it also appears that, at a given *LAmax_i* or *SEL_i*, the probability depends to a considerable degree on the indoor equivalent sound pressure level from the plane (*Li*): people who are ordinarily exposed to high levels of aviation noise while sleeping respond less to an individual aeroplane passage than people who only experience such exposure from time to time. The study findings also indicated that the type of aircraft manoeuvre (landing or taking off) did not affect the

* The figure of 40 per cent was calculated by Ollerhead by comparing all thirty-second intervals during which EEG arousals were observed in his subjects and all thirty-second intervals during which motility onset was observed[51].

probability of aviation noise-induced motility. The researchers also asked subjects about their attitude to air traffic and to the expansion of Schiphol Airport. Attitude was found to have no influence on the probability of acute motility induced by aviation noise.

The Dutch research findings are consistent with the findings of the study carried out in the USA[49]. However, the relationship between motility onset and the *LAmax* of an aeroplane passage defined on the basis of the British data is quite different from the relationship between motility and *LAmax_i* deduced from the Dutch research. The British researchers came to the conclusion that the threshold for motility onset by the noise of an aeroplane passage was an *LAmax* of 82 dB(A)[51]. If this outdoor value is reduced by 25 dB(A) (the figure given by the researchers[54] as the difference between outdoor and indoor sound pressure levels), one arrives at a threshold *LAmax_i* value of 57 dB(A). This is 25 dB(A) higher than the observation threshold determined by the Dutch researchers for motility and motility onset. In view of the pioneering nature of the British research and the significance that has long been attached to its results, the Committee considers the difference between the British and Dutch studies at more length in Annex D. Its conclusion is that the British research had certain shortcomings that the more recent Dutch research did not share.

3.2.4 *Subject-registered awakening and EEG awakening*

The relationship between the probability of subject-registered awakening and *SEL_i* illustrated in Figure 8 has been defined on the basis of a secondary analysis by Passchier-Vermeer[52]. According to this analysis, the observation threshold for aviation noise-induced subject-registered awakening is an *SEL_i* of 54 dB(A), corresponding to an *LAmax_i* of 42 dB(A).

The Committee puts the typical frequency of 'spontaneous' EEG awakenings, including short duration arousals, at ten to twelve occurrences per night and the typical frequency of 'spontaneous' subject-registered awakenings at 1.5 to two occurrences per night (in periods without noise events). If someone has woken up 'spontaneously', they will be able to hear a car, aeroplane or train that passes while they are awake. The *more frequent* and *longer in duration* the passages are, the greater the chance of hearing one after waking up spontaneously. In an extreme case, therefore, it is theoretically possible that someone could hear a passing car, plane or train ten times in the night without the associated noise being the cause of the person waking up.

The Committee found three reports on the effects of night-time noise on children's EEGs. These related to laboratory studies involving twenty-four, eight and six children, respectively[55-57] and one study of five children in their home environments[56]. Busby[55] found that children in the final third of their sleep (which mainly involves REM sleep) exhibited EEG awakening in response to noise in nearly 60 per cent of cases – albeit

involving noises of up to 95 dB(A). However, partly because of the lack of additional information regarding the cortical responses of children to night-time noise, the Committee is not able to make any definitive statement about the possibility of children being more sensitive to night-time noise than adults.

3.2.5 *Heart rate acceleration and stress hormone concentrations in the blood*

From the field research data published by Hofman *et al*[58], the Committee has calculated that peaks in the noise from a motorway (e.g. when a lorry passes) have approximately a 60 per cent chance of inducing heart rate acceleration, irrespective of the *LAmax_i*. The *LAmax_i* values recorded by the Hofman team were mostly between 30 and 70 dB(A). The average increase in heart rate worked out at four beats per minute, irrespective of the subject's sleep stage. The Committee regards heart rate acceleration as one form of acute cardiovascular change. Other acute changes directly associable with heart rate acceleration, such as acute changes in systolic blood pressure and vasoconstriction, follow the same pattern[59-63] (see Annex D). On the basis of laboratory research findings, it seems likely that the noise of a passing lorry or aeroplane with a similar *SEL_i* would have a broadly similar effect on heart rate[64-67] (see Annex D). Laboratory research has also indicated that, if one uses *SEL_i* as one's index of noise, noise events that quickly become louder at the start (such as the noise of a low-flying military jet or gunshot noise) have a greater effect on heart rate than noise events characterised by a more gradual increase in level (such as the noise of a lorry or a civil aircraft)[64,65,67]. However, it is not possible to quantify the extent of the effect.

The Committee is not aware of any field studies that have looked at acute noise-induced changes in the (stress) hormone balance. It is not surprising that no such research has apparently been carried out, since it would necessarily be highly invasive and therefore inappropriate for large-scale studies of subjects in a domestic setting.

Only one study was traced that focused on the impact that exposure to night-time noise has on children's physiological functions. In 1967, Semczuk investigated the effects of exposure to noise when sleeping, by using thoraxgraphy to monitor breathing in a study group of fifty children (five to seven years old) and a hundred adults[68]. The trigger level for respiratory changes associated with an aural stimulus (sound of a particular pitch) was 10 to 15 dB(A) lower in children than in adults. The researcher accordingly concluded that a child's autonomous nervous system is more readily activated by noise when sleeping than an adult's, and that children are therefore physiologically more sensitive to night-time noise than adults. The Committee supports this conclusion.

3.2.6 *Acute annoyance*

None of the studies reviewed by the Committee entailed the recording of acute noise-related annoyance during the sleep period, but some did involve subjects subsequently being asked questions on the topic. It is likely that making journal entries during the night would have a distorting effect by interfering with the sleep process. The Committee assumes that people do feel inconvenienced by noise during the night, even though such feelings have not actually been recorded. The subsequent logging of inconvenience by subjects serves as an indirect indicator of the existence of acute annoyance.

3.2.7 *Ranking of acute responses*

In Figure 9, the acute responses to noise are ranked in order of decreasing probability of induction by noise. Although no research into acute annoyance has been reported, the Committee considers it reasonable to suppose that inconvenience can only be experienced by a person who actually is awake.

3.2.8 *Groups with heightened sensitivity to acute effects*

The Committee has also sought to identify any evidence in the available research data that might indicate whether certain personal characteristics might be associated with heightened sensitivity to acute noise-induced effects on sleep. Although the strength of the evidence found by the Committee is limited, it does appear that people with cardio-

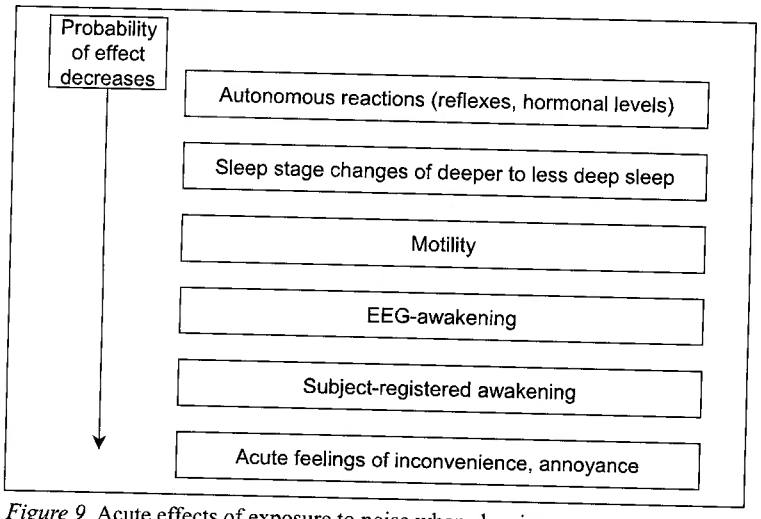


Figure 9 Acute effects of exposure to noise when sleeping.

vascular problems, people who regard themselves as particularly sensitive to noise, and children may all be particularly sensitive to acute cardiovascular effects. Because of the shortage of research data on children, it is not possible to say with confidence whether children are more sensitive than adults to other acute biological responses.

3.2.9 *Conclusions*

On the basis of the considerations set out above, the Committee draws the following conclusions:

- Road, rail and air traffic noises can induce acute responses in people who are sleeping. Response induction begins at a fairly low threshold level and becomes more likely as the intensity of the noise increases. The observation threshold for EEG awakening, motility, and motility onset associated with traffic noise is an *SEL_i* of approximately 40 dB(A); the corresponding figure for heart beat acceleration is less than 40 dB(A),), and that for subject-registered awakening (due to aviation noise) is approximately 54 dB(A). The observation threshold for EEG-detected sleep stage change is probably lower than 40 dB(A) (the relationship cannot be defined with confidence. Although there is insufficient data to provide direct evidence that road and rail traffic noise can induce subject-registered awakening, the Committee believes that peaks in road and rail traffic noise probably have the same effect as aircraft noise, although the associated observation threshold may not be an *SEL_i* of 54 dB(A). The induction of acute changes by industrial noise has not been the subject of scientific study. Nevertheless, the Committee expects that exposure to industrial noise is capable of inducing similar responses. It seems quite possible that the observation thresholds for industrial noise may be broadly similar to those for traffic noise, but the Committee draws no conclusions on this point.
- Almost no research data is available regarding the acute effects of night-time noise on children. The results of the one study that looked at children's respiratory response to noise exposure indicate that the threshold for response induction in children is 10 to 15 dB(A) lower than in adults. Because of the shortage of data, the Committee cannot exclude the possibility that children are also more sensitive than adults to acute cortical effects when sleeping; however, if so, this may only be the case during REM sleep, rather than during deep sleep.
- Laboratory research indicates that, if *SEL_i* is used as the index of noise, noise events involving a very rapid rise in intensity to their peak level have a greater effect on heart rate than events characterised by a more gradual early rise in intensity. However, the Committee is not able to quantify the effects concerned. Although what is known about the relationship between noise from military jets and subject-registered awakening is based purely on data collected from people living in the

vicinity of one airbase, and therefore needs to be verified by other pertinent scientific data, it would appear that, at high noise exposures, subject-registered awakening is much more likely to be induced by military jets than by civil aircraft. The Committee suspects that the increased probability of subject-registered awakening in response to louder military jet passages is linked to the great speed with which the noise from the approaching jet increases in intensity, thus inducing feelings of anxiety.

- The *more* noise events a person is exposed to per night, the greater the chance is that he or she will happen to hear one of the noises after waking up 'spontaneously'. The Committee believes it is reasonable to assume that, broadly speaking, between 1,5 to two times and ten to twelve times per night, a person is sufficiently conscious to coincidentally hear a noise event that has not actually awoken him or her. This may help to explain the extent of night-time noise-related annoyance. At a given *Lnight* value, the probability of coincidentally hearing a noise event after waking up will often be considerably greater with road traffic than with air and rail traffic, since road traffic noise involves frequent lower-level noise events, in addition to the peaks.
- Although the strength of the evidence is limited, it may well be the case that (as indicated above) people with cardiovascular problems, people who regard themselves as particularly sensitive to noise, and children are particularly sensitive to the acute cardiovascular effects of noise.

The results of the research into the acute effects of exposure to night-time noise when sleeping are summarised in Figure 10. The upper element of the diagram illustrates the general principle: night-time noise influences sleep in a way that can be measured by

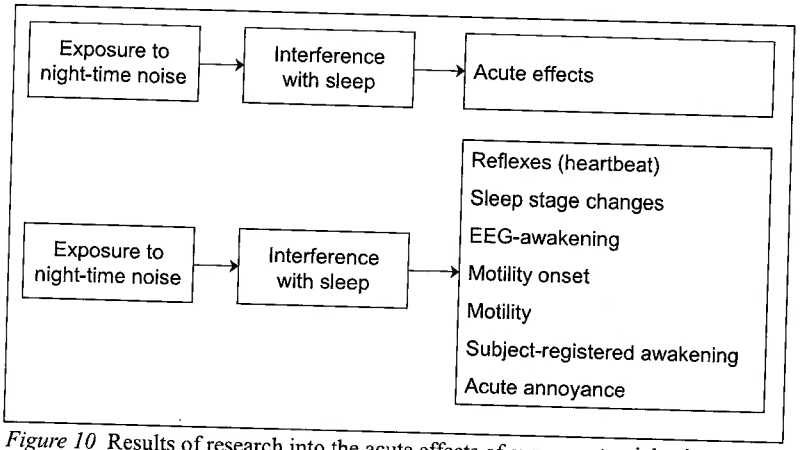


Figure 10 Results of research into the acute effects of exposure to night-time noise when sleeping.

reference to acute effect parameters. The lower element of the diagram indicates which parameters appear to be affected by noise during the sleep period. All acute responses to noise are regarded as biological effects by the Committee.

3.2.10 *Strength of the evidence*

Exposure to noise during the sleep period induces immediate physical responses. Table 4 lists the effects concerning which there is sufficiently strong evidence to conclude that they occur as a direct result of noise events during the night-time sleep period.

Table 4 Acute biological effects.

Cardiovascular changes[a]
Sleep stage change, from deeper to less deep sleep
EEG awakening
Motility onset
Motility
Subject-registered awakening

[a] The advisory report focuses mainly on heart beat acceleration, but there is also sufficient evidence of the induction of vasoconstriction and acute blood pressure rises.

There is no evidence that an acute change in (stress) hormone levels can be induced by exposure to night-time noise when sleeping, but one may assume that this is the case. It is not, however, possible to investigate the possibility in a field study, since such research would involve the use of invasive monitoring techniques. Also, there is only limited indirect evidence that noise events can induce acute annoyance.

3.3 Biological effects before, while and after sleeping

The scientific situation as described in an earlier Health Council report

To support preparation of the previously mentioned Health Council report on aviation noise and sleep, Hofman[17] also summarised the results of research published up to 1991 that had looked into the effects that exposure to night-time noise has during the course of a night or a day and over a longer timescale. Hofman's findings are presented in Table 5. As was the case with research into acute effects, the research referred to in the table related mainly to noise from road and air traffic, but one or two of the reviewed studies were concerned with the effects of noise from rail traffic or industrial activities.

Table 5 The results of research published up to 1991 relating to the effects of exposure to night-time noise events, as reviewed by Hofman[17].

Effect registration method	Effect	Number of studies in which significant change was observed	Number of studies in which no significant change was observed
Journal/cognitive testing	Over a night or day		
	- Diminished sleep quality	15	10
	- Daytime irritability and impaired cognitive performance	8	6
	- Sleep disturbance	25	2
Questionnaire	Over the longer term		
	- Night-time noise-related annoyance	42	2
	- Seeking healthcare	6	5
	- Increase in self-reported health problems	10	8
	- Increase in the use of somnifacient drugs and sedatives	8	5

As indicated in the table, almost all studies found that increasing night-time noise exposure was associated with statistically significant rises, particularly in long-term annoyance and sleep disturbance (difficulty getting to sleep, waking up in the night, waking up too early in the morning and not being able to get off to sleep again). In line with Hofman's review[17], the table provides no information about exposure levels or study quality.

Only a small number of field studies looked specifically at the relationship between noise exposure and its effect on sleep latency time, sleeping time, or the post-sleep period. Furthermore, research data on acute noise-induced changes (see section 3.3) has not in most cases been aggregated to provide full-night data. Most of the information presented below relates to research into the effects of road traffic and aviation noise. In most of the reviewed studies, several effect parameters were studied at once, which has made it difficult for the Committee to present a summary structured along the lines of the previous section (on acute effects). This section begins with a discussion of the results of research into the influence of road traffic noise, which is followed by a subsection on the effects of aviation noise. Consideration is then given to the findings of field research into the effects of night-time noise on motility and on stress hormone concentrations. Finally, the Committee addresses the possibility that immune functions might be influenced by exposure to night-time noise, which has been investigated only in the context of laboratory research.

3.3.1 *Road traffic noise: various effect parameters*

In 2003, the RIVM published a review of field research concerned specifically with the effects of night-time *road traffic* noise on sleep[69]. In the eleven reviewed studies that involved the use of sleep EEGs, ECGs or actimetric measurements and sometimes of journals, noise was also measured (in the bedroom) during the study nights.

Five of the eleven studies were deemed unsuitable for inclusion in the detailed analysis for various reasons (too small, no usable findings). Useful data was produced by four intervention studies carried out on behalf of the European Commission between 1980 and 1983. By increasing the acoustic insulating properties of bedroom windows, using personal hearing protection gear and sleeping on the quiet side of the house, the road traffic-related noise exposure was reduced by approximately 10 dB(A) on half of the subject-nights[58,59,70-73]. The studies in question involved a total of seventy people and 922 subject-nights. Jurriëns drew the following conclusions regarding the effects observed in relatively noisy situations (compared with quieter situations after intervention)[70]:

- The average duration of REM sleep is 6.5 minutes shorter (in adults, REM sleep normally lasts for approximately two hours).
- In reaction time tests, the average reaction time is twelve milliseconds (12 ms) longer than the overall average reaction time of 350 ms, and more mistakes are made (8 per cent)
- Self-reported quality of sleep is less (7 per cent)
- The W (waking) time recorded by EEG is 7 minutes longer (determined in two of the four studies)
- The average heart rate when sleeping is higher. In the Dutch research, the rate was 3.2 beats per minute higher (71.5 bpm, compared with 68.3 bpm)[58].

A study by Öhrström[74], which involved the use of journals only, was also included in the RIVM review. In this study, it was found that in situations characterised by higher levels of road traffic noise at night, people had more difficulty getting to sleep, were more likely to be woken up in the night by traffic noise, had poorer sleep quality and were more likely to be tired and irritable in the morning. The same research team recently completed a small longitudinal intervention study with adults and a cross-sectional study with children and adults, neither of which found that exposure to night-time road traffic noise had any statistically significant effect on the studied effect parameters[75,76].

The RIVM review additionally took in a German study of road and rail traffic noise[77,78]. This study's findings regarding average motility are discussed in more detail later.

3.3.2 *Aviation noise: various effect parameters*

A report by Passchier-Vermeer[12] defines the relationship between *aviation noise* and each of several effects on sleep over one sleep period (see Figure 23 in Annex D). The effect variables were: high motility for the subject's age; recalled aviation noise-induced awakening; subject-registered awakening three or more times per night; use of somnifacient drugs. The use of somnifacient drugs and sedatives rose markedly with increasing night-time noise exposure mainly among older subjects. Night-time aviation noise did not appear to have any effect on subjects' performance in reaction time tests taken at the end of the evening. The degree of subject-reported morning drowsiness (as indicated at 10am) did, however, appear to be related to night-time noise exposure: the greater the overnight exposure, the sleepier subjects felt in the morning.

The Passchier-Vermeer study also indicated that increased aviation noise exposure (equivalent sound pressure level) during the sleep latency period was associated with prolonged sleep latency and greater difficulty getting to sleep. People who when they went to bed were concerned about the possibility of being disturbed by aviation noise took an average of a quarter of an hour longer to go to sleep than the people that were not concerned.

3.3.3 *Road, rail and air traffic noise and motility*

In the above-mentioned German research into *road and rail traffic noise*[77,78] 188 subjects were exposed mainly to road traffic noise and a similar number mainly to noise from passing trains. The number of subject-nights with results on motility was 1710 in the road traffic group and 1581 in the rail traffic group. A recent analysis[79] of the data indicated that, among people exposed to *rail traffic noise*, average motility for a single sleep period was unrelated to the equivalent indoor or outdoor traffic sound pressure level during the period in question, whereas an increase in such levels was associated with a statistically significant rise in motility among people exposed to *road traffic noise*. The Dutch sleep disturbance study also found that average motility rose with increasing *aviation noise* exposure during the sleep period[12]. With road traffic noise, the increase in average motility per dB(A) rise in noise exposure was approximately 30 per cent greater than with aviation noise.

The Bristol-based team of Smith *et al*[80] made a phased investigation of the interrelationships between aviation noise, sleep disturbance and health. In the final phase, the motility of ninety people (forty-five couples) was monitored using actimeters for three nights, during which sound pressure levels were measured in the subjects' bedrooms. The sources of the noises audible in the subjects' bedrooms were not objectively deter-

mined, nor were any outdoor sound pressure levels measured. The study revealed no relationship between noise exposure and average actimetric level over the course of a night. The researchers took the view that this was mainly because the noise exposures experienced by the subjects were low.

3.3.4 *Road traffic and aviation noise: stress hormone concentrations*

Babisch[81] produced a survey of research into the effects of *road traffic and aviation noise* on hormone concentrations (adrenaline, noradrenaline, cortisol) determined from urine samples collected over the course of a night and in one study from saliva samples taken after awakening (for the measurement of cortisol only). In all, the survey took in eight field studies (see Tables 16 and 17 in Annex D).

In seven of the studies, the subjects were children, who in five studies were exposed to aviation noise and in two studies to road traffic noise. No link was found between exposure to aviation noise and cortisol concentrations, but higher road traffic noise exposures were associated with statistically significant rises in levels of this hormone. Adrenaline and noradrenaline concentrations exhibited statistically significant rises at higher aviation noise exposures in two of the four studies, but could not be linked to road traffic sound pressure levels in one study (not all of the studies involved monitoring concentrations of all three of the hormones referred to). Whether the increased hormone concentrations were brought about by exposure to night-time road traffic noise is unclear; they could also have been an after-effect of daytime noise exposure.

The only field study involving adult subjects focused on the effect of road traffic noise on the quantity of adrenaline and noradrenaline in the night-time urine of 234 women ages thirty to forty-five[82]. Among the women whose bedrooms were on the street side of their homes, increasing traffic volume (and therefore increasing equivalent sound pressure level) was associated with a statistically significant increase in noradrenaline concentration, but no link was established between traffic volume and adrenaline concentration. Among women whose homes had the living room on the street side, traffic volumes had no apparent influence on either adrenaline or noradrenaline concentrations. The fact that it was mainly noradrenaline concentrations that were raised is consistent with Ising's model, which predicts that noradrenaline concentration is particularly likely to increase in response to noise to which a person has in part habituated[83]. The effect of road traffic noise on noradrenaline concentration was particularly pronounced in women who indicated that they slept with the bedroom window closed to prevent their sleep being disturbed by road traffic noise. Among women who experienced no noise-related annoyance when their windows were closed, no statistically significant increase in noradrenaline concentrations was observed.

The modest amount of data available on this subject prevents the Committee drawing any firm conclusions. It does nevertheless appear that, under certain circumstances, exposure to noise can lead to raised stress hormone levels in sleeping adults; the possibility that noise can have a similar effect on children cannot be excluded. More definite conclusions must await the availability of further research data.

3.3.5 *Various noises in laboratory research: immune function*

Between 1968 and 1974, Osada *et al*[84-87] investigated immunological parameter changes associated with exposure to noise. However, the major changes observed in the four laboratory experiments with twenty-one subjects were almost certainly attributable to shortcomings in the study design*. The Committee is not aware of any other research into the influence of night-time noise exposure on immune functions.

In their survey article *The Neuroendocrine Recovery Function of Sleep*, Born and Fehm devoted a section to the possibility that night-time exposure to noise might affect the immune system[88]. On the basis of two experiments in which subjects were either deprived of sleep or allowed to sleep 'normally', the two authors postulate that night-time noise exposure may have a negative influence on the immune system. They add, however, that a great deal more research would be necessary to confirm such a hypothesis.

3.3.6 *Conclusions*

On the basis of the considerations set out above, the Committee draws the following conclusions regarding biological effects over the course of a night (before, while and after sleeping):

- There is sufficient evidence that, above a given threshold noise exposure, exposure to road and air traffic noise while sleeping is associated with the following:
  - Increased difficulty getting to sleep
  - Increased sleep latency period
  - Use of somnifacient drugs and sedatives, particularly among older people
  - Reduced REM sleep and increased time in a conscious state, as determined by EEG
  - Raised average heart rate
  - Raised average level of motility
  - More frequent subject-registered awakening
  - More frequent recalled noise-induced awakening

* Marth, personal communication.

- Reduced self-reported quality of sleep
- Increased drowsiness, tiredness and irritability

- There is limited evidence that exposure to road and air traffic noise while sleeping is associated with the following:
  - Increased daytime irritability
  - Impaired daytime cognitive performance
- Exposure to rail traffic noise has been investigated on an incidental basis only: no statistically significant rise in average motility during a sleep period was detected in response to exposure. No research has been carried out into the consequences of exposure to industrial noise.
- Little is known about the influence of exposure to night-time noise on immune functions.
- There is limited direct evidence that, under certain circumstances, exposure to night-time noise can influence (stress) hormone levels when sleeping; this effect was observed in women who were troubled by noise during the night and were unable to relieve the problem. The Committee suspects that noise has no consistent effect on stress hormone levels, and that any effects depend partly on personal and situational factors. More definite conclusions must await the availability of further research data.

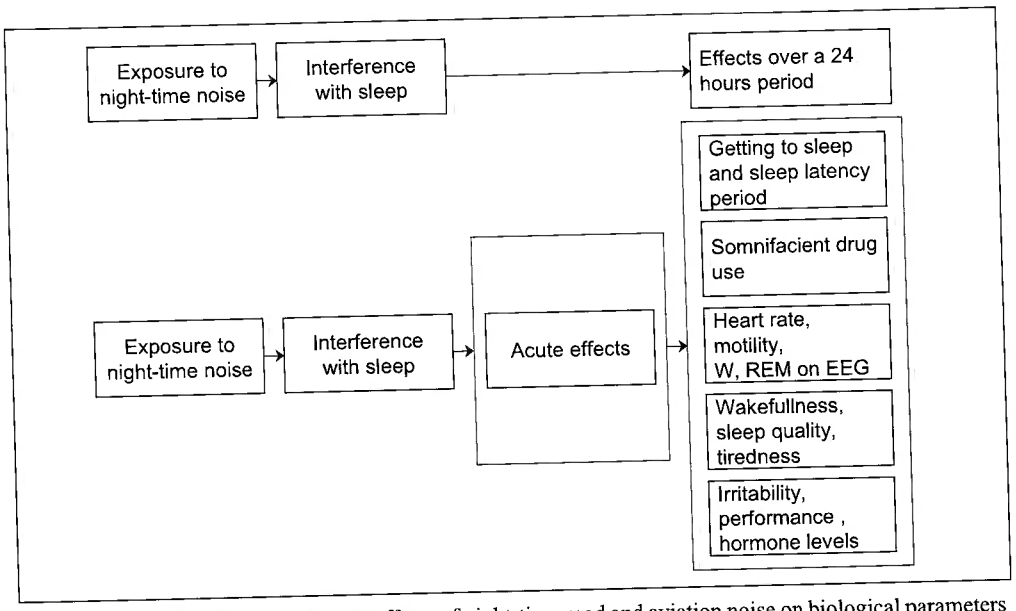


Figure 11 Results of research into the effects of night-time road and aviation noise on biological parameters over the course of a night (before, while and after sleeping). There is sufficient evidence of a causal relationship between exposure and the parameters in the upper four effect boxes, but only limited evidence of such a relationship with the parameters in the bottom effect box.

Figure 11 indicates which parameters appear to be affected by road and aviation noise during the sleep period. There is sufficient evidence of a causal relationship between exposure and the parameters in the upper four effect boxes, but only limited evidence of such a relationship with the parameters in the bottom effect box.

3.3.7 *Biological effects as predictors of impact on health and well-being*

In some cases, there is empirical data indicating that a biological effect of night-time noise can, after repeated exposure and under certain circumstances, ultimately have consequences for a person's health and well-being. Where certain other biological effects are concerned, although no such data is available, it is plausible that chronic exposure to night-time noise when sleeping may lead to physical responses indicative of a negative influence on health and well-being. The Committee's assessment regarding each of the effects concerned is given in Table 6.

Table 6 Biological (physiological and psycho-physiological) effects for which there is either sufficient or limited evidence of a causal relationship with night-time noise and which could plausibly have a negative influence on health and well-being in the event of chronic exposure[a].

Variable	Probability of negative implications for health and well-being
Difficulty getting to sleep, difficulty staying asleep	Empirical data
Change in cardiovascular activity	Plausible
Increased motility	Plausible
Changes in duration of various stages of sleep and in sleep structure, fragmentation of sleep	Empirical data
Changes in (stress) hormone concentrations	Plausible
Waking during the sleep period and/or prematurely in the morning	Empirical data
Drowsiness/Tiredness during the day and evening	Plausible
Impaired cognitive performance	Plausible
Increased irritability	Plausible

[a] The effects in question can occur after a single night's exposure. However, there is no empirical evidence that the occurrence of any of the effects in the context of a single night's exposure can influence health or well-being, nor is it plausible that this might be the case. The effects after a single night's exposure all come under the heading 'no empirical evidence of implications for health and well-being and no plausible causal association'.

3.4 The effects of long-term exposure

In field research with subjects who are exposed to noise on a nightly basis, it is not easy to distinguish the effects of a single disturbed night from the effects of long-term exposure. In many cases, the way relationships are defined depends on what is known about the noise exposure. Where the available data concerns sound pressure levels on particular nights, observed effects are typically related to such data. However, if the only available data consists of estimates of longer-term noise exposure, observed effect parameters are considered representative of the consequences of prolonged exposure. Making a distinction is therefore important mainly in the context of research data structuring. The consequences of noise-related sleep disturbance described in section 3.3 can therefore also be seen as the effects of long-term exposure, since our knowledge of them comes from data concerning people who have experienced chronic exposure to environmental noise. Hence, the Committee also considers the effects listed in Figure 11 to be the effects of long-term exposure.

3.4.1 Insomnia

A group of Japanese researchers carried out a questionnaire-based survey of 3600 adult Japanese women (aged between twenty and eighty) to gather information about the factors that contribute to insomnia[89]. Some 11 per cent of subjects were found to be affected by insomnia (as defined on the basis of the WHO's ICD10 classification system[90]). Analysis of the survey data took account of various distorting variables, such as age, number of (small) children in the family, social status, receipt of medical treatment, regularity of bedtimes, apnoea-like problems and serious unpleasant experiences in the six months prior to completing the questionnaire. When the percentage of insomniacs in each of the three areas with the highest exposures was compared with the percentage in the low-exposure areas, the ratios worked out at, respectively, 1.4 (2100 vehicles per hour, *Lnight* of around 65 dB(A)), 2.1 (2400 vehicles per hour, *Lnight* of around 67 dB(A)) and 2.8 (6000 vehicles per hour, *Lnight* of around 70 dB(A)). The most frequently reported problem was difficulty getting to sleep.

The seriousness of the problems caused by insomnia is illustrated by the quality-of-life weighting system developed by Stolk and Van Busschbach[91,92], under which insomnia has a quality-of-life weighting of 0.83. This means that a year affected by insomnia results in the loss of 0.17 DALYs.

Research into the effects of exposure to air and road traffic noise has shown that increases in night-time noise exposure or in noise exposure during the sleep latency

period have a statistically significant adverse impact on subjects' ability to get off to sleep and on sleep inception periods[12,13,93,94].

3.4.2 *Hypertension*

In the context of a longitudinal study (Spandauer Gesundheits Survey)[95], the health of adults in Berlin's Spandau district has been surveyed every two years since 1982. The ninth survey round involved 2015 subjects. In addition to going through the usual tests and questionnaires, 1718 (85 per cent) of these subjects were asked about noise-related annoyance from road, rail and air traffic, as well as from industrial sources (see Annex D). Hence, the noise research element of the study took the form of a cross-sectional study. The noise exposure was estimated using noise calculation models. The estimates made for aviation noise are not regarded as reliable by the Committee, but those for road traffic noise do not suffer from the same shortcomings. Furthermore, the road traffic noise exposure was measured on an incidental basis both during the day and at night. Details of the subjects' medical treatment histories over the two years since the previous survey and over the entire research period were gathered in interviews with the subjects. The findings showed that, after taking account of other factors that could explain any association between medical condition and noise exposure, the prevalence of hypertension was higher (by a statistically significant margin) among people for whom the *road traffic*-related *Lnight* was more than 55 dB(A) than among people for whom the road traffic-related *Lnight* was less than 50 dB(A) (odds-ratio 1.9). Prevalence among people for whom the road traffic-related *Lnight* was between 50 and 55 dB(A) was at an intermediate level. However, no statistically significant association was found between the prevalence of hypertension and road traffic noise *during the day*. The researchers suggest that hypertension is associated with nigh-time exposure but not with daytime exposure partly because people are often elsewhere during the day and partly because people are more sensitive to noise at night than during the day.

The Committee considers the following points to be relevant to the assessment of the research findings outlined above:

- The investigated outcomes: use of personal statements as the only means of determining whether subjects were receiving medical treatment for conditions such as hypertension. This may have led to considerable distortion of the research results. Although the report speaks at length about tests such as blood pressure measurement and the registration of medicine use, the resulting data is not used in the analyses. The Committee takes the view that if the measured data had been used for the analyses or – even better – if the analyses had been based entirely on measured data, the findings would have carried more weight.

- The researchers point out that the study population was made up largely of people who were very conscious of their health. In other words, the subjects were self-selected and this may also have led to distortion. The point being that, if night-time noise does have an effect on health and well-being, making people feel uneasy about their health, they may well be inclined to report all sorts of other problems that they don't really have. This could have resulted in the prevalence of hypertension among the most heavily exposed group being overestimated.
- The researchers do not report the raw data, i.e. the data in its original form, uncorrected for other factors capable of distorting the relationship between night-time noise exposure and the probability of developing a condition (confounding). It is therefore difficult to estimate how important these factors were and how plausible their supposed influence on the relationship between probability of hypertension and night-time noise exposure was.

On the basis of the considerations outlined above, the Committee has concluded that, although a link between night-time noise and increased risk of hypertension is plausible, the Spandau survey does not provide sufficient evidence of a causal association.

In this context, the Committee would point out that, in the 1994 report *Noise and Health*[2], an international Health Council Committee concluded on the basis of data from various, mostly German, studies that a causal relationship did probably exist between daytime noise exposure and hypertension risk. It was suggested that the observation threshold was an equivalent sound pressure level of 70 dB(A) over the course of a day. Consideration was not given to the possibility that night-time noise exposure might be at least partly responsible for the increased probability of hypertension associated with what it should be said are very high noise exposures. The Committee would like to see the possibility explored of re-analysing the data in a way that takes night-time noise exposures into account.

3.4.3 *Motility*

British research into the effect of aviation noise on sleep has revealed that the average probability of motility (motor unrest) during the course of a sleep period rises with increasing exposure to air traffic noise[96]. Horne reported that there was a strong relationship between average motility and perceived quality of sleep. Dutch field research into the effect of aviation noise on sleep and German research regarding the effect of road traffic noise has also found that average motility (motor unrest) increased with noise exposure when sleeping[12,13,79]. However, no association has been detected between motor unrest and rail traffic noise. Furthermore, the increase in motility with the *Li* of air and road traffic noise proved to be much greater than might be expected on the basis of

accumulated acute noise-related motility. The Committee believes that this phenomenon can be explained if one assumes that chronic exposure increases the physiological arousal level when sleeping, not only in the periods of the night when vehicles or aeroplanes are passing, but also when there is no traffic. In the Dutch field research into the effects of aviation noise on sleep, it was observed that overnight average motility was strongly associated with the number of occasions that a subject recalled waking during his or her sleeping time, with the number of subject-registered awakenings during this time, and with a series of variables determined from the questionnaire completed by the subject at the beginning of the study. The variables in question were: whether the subject used somnifacient drugs; quality of sleep; number of sleeping problems; number of times awoken by aviation noise; number of times per week aviation noise had a negative effect on sleep; health problems included on the abbreviated Health Perceptions Questionnaire ('VOEG-lijst').

The observed relationship between average motility and various negative consequences of exposure to night-time noise is regarded by the Committee as a strong indication that increase in average motility should also be seen as a negative consequence of exposure to noise when sleeping.

3.4.4 *Self-reported sleep disturbance*

On the basis of TNO's Disturbance Knowledge Base, exposure-response relationships have been defined for self-reported sleep disturbance by road, rail and air traffic[97,98]. The associated TNO reports contain various assessments of factors that influence sleep quality (problems caused by waking up in the night, waking up too early in the morning, night-time noise-related annoyance). Just as 'annoyance' is covered by an international definition, so high sleep disturbance is defined as a score of 72 or more on a scale of 0 (no sleep disturbance at all) to 100 (extreme sleep disturbance). The relationships between the various kinds of traffic noise and self-reported high sleep disturbance are illustrated in Figure 12.

From Figure 12, it will be apparent that, at a given *Lnight* value, aviation noise is linked to slightly more self-reported high sleep disturbance than road traffic noise, while rail traffic noise is associated with less disturbance than either of the other sources. The illustrated relationships are closely consistent with the provisional curves presented in 1997 in the Health Council's advisory report *Assessing Noise Exposure for Public Health Purposes*[8].

However, when one looks at the relationships between *Lnight* and the percentages of people experiencing 'at least sleep disturbance' and 'at least slight sleep disturbance', one finds that the relative positions of road traffic noise and aviation noise are reversed. It is worth noting that less certainty exists regarding the relationships between distur-

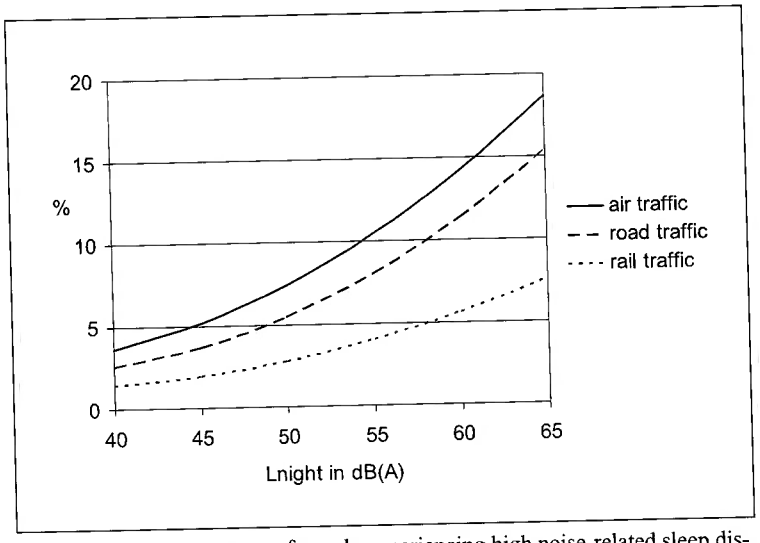


Figure 12 The percentages of people experiencing high noise-related sleep disturbance attributable to air, road and rail traffic, as a function of *Lnight*[97,98].

bance and aviation noise than regarding the relationships involving road and rail traffic noise.

The RIVM report[69] mentioned in 3.3.1 considers the question of whether a quantitative meta-analysis could be made of the results of questionnaire-based research into the influence of road traffic noise on perceived quality of sleep and on awakening. Although the RIVM describes several studies as being good quality, the researchers decided that it was not possible to perform a meta-analysis because of discrepancies in the studies' nomenclature, methods, exposure determination techniques and approaches to adjustment for distorting variables. Their ultimate conclusion was therefore that there were indications that road traffic was associated with reduced perceived quality of sleep and more frequent (or more prolonged) night-time awakening.

Leidelmeier and Marsman[99] carried out an interview-based study of 1242 households in the Netherlands, in which subjects were asked about daytime and night-time noise from neighbours and any associated annoyance. Distinction was made on the basis of the part of the house in which the noises were audible and any associated annoyance was experienced. Subjects proved least tolerant of noise from their neighbours that was audible in the master bedroom. The researchers distinguished five types of noise, which are listed below, along with the percentage of subjects who indicated hearing the relevant type of noise from a neighbouring dwelling at night in the master bedroom:

- Contact noise 22 per cent
- Noise from sanitary fittings, central heating, etc 19 per cent
- Noise from radio, TV and hi-fi 12 per cent
- Do-it-yourself (DIY) noises 8 per cent
- Pets 6 per cent

Where each of the five investigated types of noise were concerned, roughly 10 to 15 per cent of subjects indicated that they felt it was unacceptable for the noise to be audible during the day. Overall, nearly 30 per cent of subjects said that sanitary fittings should not be audible at night, while approximately 50 per cent felt each of the other four types of noise were unacceptable by night.

In 1993, Kranendonk *et al* produced a synthesis of the research conducted up to that point in time into the annoyance associated with noise from neighbours[100]. Subsequently, in 1998, Van Dongen *et al*[101] published a report on the relationship between noise from neighbouring dwellings and the airborne and contact noise attenuating indices I_{lu}, $I_{lu;k}$, and I_{co}, drawing on data from a questionnaire-based survey of the residents of six hundred dwellings, whose acoustic quality was determined in 202 cases. The results of the two studies are reasonably consistent (see Annex D). Both found that the chief causes of annoyance were loud radios, hi-fis and TVs, audible and sometimes intelligible voices, the slamming of doors and footsteps on floors and staircases. In both cases, it proved that, when I_{lu} had a value of 0 (the minimum requirement for new homes), 10 per cent of subjects reported high annoyance and 15 per cent reported annoyance caused by noise from neighbouring dwellings. These figures are not specific to night-time noise, but apply to annoyance over a twenty-four-hour period.

On the basis of the findings outlined above, the Committee concludes that the standard of inter-dwelling sound attenuation presently required does not provide sufficient protection to prevent annoyance caused by noise from neighbours. Since people are less tolerant of the noise their neighbours make at night-time than of their neighbours' evening or daytime noise, it may be assumed that much of the annoyance associated with noise from neighbours relates to the influence of such noise on sleep. The Committee returns to this point when addressing the State Secretary's questions.

3.4.5 *Health problems*

The Dutch field research into the effects of aviation noise on sleep established a relationship between personal noise exposure when sleeping (*Li*) and the frequency of health problems included on the abbreviated Health Perceptions Questionnaire[12,13]. Compiled on the basis of stress research, the Health Perceptions Questionnaire identifies

thirteen health-related problems, such as headache, stomachache, tiredness and digestive problems. It will be apparent that these are not life-threatening conditions. A rise in aviation noise-related *Li* from 0 to 35 dB(A) is associated with a two-fold increase in the frequency of problems. Various factors that might be expected to influence the relationship between noise and problem frequency, such as what time a person wakes up and whether they sleep with their bedroom window open, prove not to be influential in practice. The Committee interprets these findings as a strong indication that exposure to night-time aviation noise causes a rise in the incidence of health problems.

3.4.6 *Complaints about night-time noise*

The Committee believes that the submission of a complaint about noise is symptomatic of reduced well-being. Numerous factors influence a person's inclination in a given situation to make an 'official' complaint about a noise-related problem. It is not therefore possible to draw any general conclusions on the basis of what happens in a given situation. In the Netherlands, people can make complaints about, for example, the annoyance caused by noise from aircraft using Schiphol Airport, by noise road, rail and air traffic in the Rijnmond area, by events, and by industrial sources. Analysis of these complaints shows that, relatively speaking, night-time noise generates more complaints than daytime noise (see Annex D).

3.4.7 *Conclusions*

The Committee draws the following conclusions:

- Above a certain observation threshold, exposure to road and air traffic noise while sleeping has the following chronic consequences (where the strength of the evidence for a causal relationship is indicated between brackets):
  - Insomnia (sufficient evidence)
  - Increase in average motility (sufficient evidence)
  - Self-reported sleep disturbance (sufficient evidence)
  - Increase in self-reported health problems (sufficient evidence)
  - Submission of complaints (sufficient evidence)
  - Reduced sleep quality (sufficient evidence)
  - Increased use of somnifacient drugs and sedatives and increased reference to healthcare professionals (sufficient evidence)
  - Increased daytime irritability (limited evidence)
  - Impaired cognitive performance (limited evidence)
  - Impaired social contacts (limited evidence)

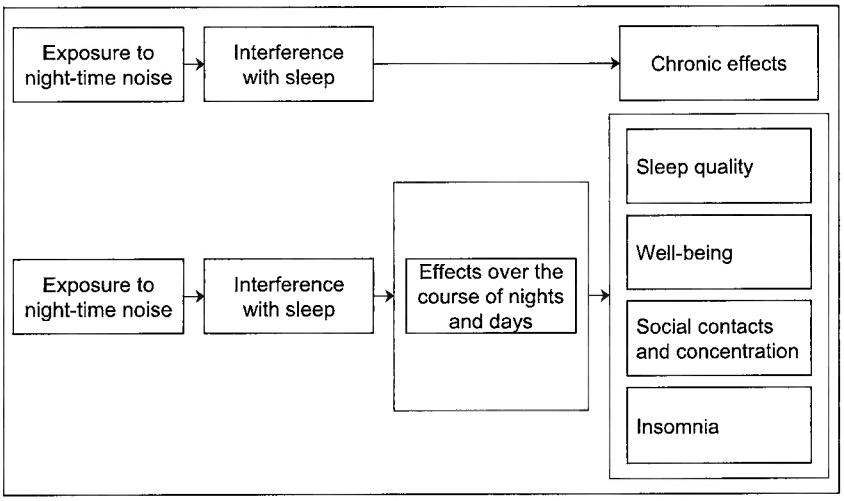


Figure 13 Results of research into the influence of exposure to night-time road and aviation noise on long-term health and well-being parameters.

- The effects of exposure to rail traffic noise have been studied only on an incidental basis. Average motility when sleeping was not found to be discernibly increased by such exposure. At a given *Lnight* value, the percentages of people experiencing self-reported slight sleep disturbance, sleep disturbance and high sleep disturbance due to rail traffic noise were slightly lower than the percentages experiencing such problems in connection with road traffic noise and aviation noise
- No information is available about the consequences of chronic exposure to industrial noise.

The findings outlined above are summarised in Figure 13. The effects referred to in the figure should be interpreted as follows:

- Social contacts and concentration: impaired social contacts and impaired performance of cognitive tasks
- Well-being: self-reported sleep disturbance, self-reported health problems, use of somnifacient drugs and sedatives, increased daytime irritability
- Sleep quality: reduced perceived sleep quality, difficulty getting to sleep and staying asleep, awakening, reduced sleeping time, increased average motility when sleeping.

3.4.8 *The influence of noise on sleep: correlations with sleep disorders and sleeping problems*

Thus far, consideration has been given to studies into the relationship between night-time noise exposure and the characteristics of sleep, health and well-being. Such charac-

teristics may be objectively measured (sleep latency period; EEG parameters; average motility; physiological and endocrine functions; reduced cognitive performance) or self-reported (difficulty getting to sleep; difficulty staying asleep; reduced sleep quality; waking up in the night; tiredness/drowsiness during the day; night-time noise-related annoyance; health problems; insomnia). A number of these characteristics are closely related to the characteristics of sleeping problems and insomnia generally observed in the population at large (see Annex E). Clearly, the disturbance of sleep by night-time noise is a matter of influence by an external factor, whereas the occurrence of insomnia and other sleeping problems in the population at large is probably attributable largely to personal characteristics; nevertheless, the Committee believes it is reasonable to assume that the same physical and mental processes are involved. Hence, it is plausible that sleep disturbance by environmental noise might contribute to the development or occurrence of female depression, hypertension, cardiovascular disease and occupational accidents, since all these phenomena are known to be associated with sleeping problems and insomnia. The size of any such contribution cannot be estimated. The evidence for such a link is indirect and limited in its strength.

It is plausible that people who suffer from insomnia or other sleep disorders that cause them to wake up frequently at night are more likely to be troubled by night-time noise. Insomnia is particularly prevalent among people with physical pain, dementia, depression, hypertension, heart and respiratory illness, and among older people and women who are pregnant or have been pregnant in the last twelve months. Age is not in itself a determining factor in the occurrence of insomnia or sleeping problems, which are attributable more to the accumulation of various age-related phenomena, such as lack of physical activity, changed eating and drinking patterns, dissatisfaction with one's social environment, illness and other medical conditions (see also Annex E).

People who work night shifts have to sleep by day, at least some of the time. Since in the daytime it is generally much noisier both indoors and outdoors than at night, people with variable working hours often have to sleep under less favourable circumstances than most of the population. Furthermore, such people tend to suffer some degree of disturbance to their sleeping-waking rhythm, as a result of which they frequently experience reduced-quality sleep even on the nights when they can go to bed at a 'normal' time. Consequently, night-shift workers are particularly sensitive to effects of night-time noise.

The Committee believes that certain groups of people are more likely to suffer adverse effects if exposed to night-time noise, and that this should be taken into account. The groups in question are as follows: older people; women who are pregnant or have been pregnant in the last twelve months; people who work night shifts; and people who

suffer from sleep disorders, physical pain, dementia, depression, hypertension, cardiovascular disease or respiratory illness.

3.4.9 *Strength of the evidence*

The Committee's conclusions regarding the associations between exposure to night-time noise when sleeping and changes in health and well-being are summarised in Table 7. The effect parameters which the Committee has grouped under the five categories are specified individually and in each case an indication is given of the strength of the evidence for a causal relationship between the effect parameter in question and night-time exposure to noise when sleeping. With regard to the long-term health and well-being implications of exposure to night-time noise during the sleep period, the Committee's overall conclusion is that there is sufficient evidence that such exposure leads to reduced sleep quality and reduced general well-being, and limited evidence that it leads to impaired social contacts and concentration, increased probability of developing medical conditions and reduced life expectancy.

Table 7 Effects on health and well-being of prolonged exposure to noise during the sleep period.

	Effect parameter	Evidence
Sleep quality	Reduced perceived sleep quality	Sufficient evidence
	Difficulty getting to sleep, difficulty staying asleep	Sufficient evidence
	Sleep fragmentation, reduced sleeping time	Sufficient evidence
	Increased average motility when sleeping	Sufficient evidence
Well-being	Sleep disturbance	Sufficient evidence
	Health problems	Sufficient evidence
	Use of somnifacient drugs and sedatives	Sufficient evidence
	Increased daytime irritability	Limited evidence, plausible
Social contacts and concentration	Impaired social contacts	Limited evidence, plausible
	Impaired cognitive performance	Limited evidence, plausible
Medical conditions	Insomnia	Sufficient evidence
	Hypertension	Limited, indirect evidence, plausible
	Depression (in women)	Limited, indirect evidence, plausible
	Cardiovascular disease	Limited, indirect evidence, plausible
Reduction in life expectancy (premature mortality)	Occupational accidents	Limited, indirect evidence, plausible

3.5 Prevalence and disease burden

3.5.1 *Quantification*

The prevalence of an effect that is attributable to night-time noise in an exposed population is the difference between the number (or percentage) of people in the exposed population who experience the effect in question and the corresponding number (or percentage) of people in an unexposed population with otherwise similar personal and demographic characteristics.

By taking account of the extent and seriousness of an effect, the associated disease burden on a population can be calculated. The disease burden of an effect is an index of the reduction that the effect in question causes within a population in the number of healthy years of life, expressed in units such as DALYs (*Disability Adjusted Life Years*)[33,102].

In order to make a very rough estimate of the prevalence of the effects of night-time traffic noise on sleep, and thus on health and well-being, one first requires data on the distribution of exposure to night-time noise in the Dutch population. Such data is available, albeit in the form of rough estimates, within the RIVM; see Annex G. By linking this data to the exposure-effect relationships described in this advisory report, it is then possible to estimate the prevalence of an effect in the Dutch population.

In order to determine the disease burden of an effect, it is necessary to know the weighting factor for the calculation of the associated DALYs[91,92]. However, scientific consensus is as yet lacking with regard to the weighting factors for certain effects[32].

3.5.2 *Biological effects*

The Committee has divided biological effects into two groups: acute effects and effects over the course of a night (before, while and after sleeping).

In order to estimate the prevalence of acute effects, such as being woken by night-time noise, it is necessary to have nationwide data on the distributions of traffic noise *SEL* or *LAmax* values. Because sleeping times should preferably be included in the calculations, but are subject to considerable inter-personal variation, one ought to additionally know how *SEL* or *LAmax* values are distributed in various periods e.g. in each hour covering the overall spread of sleeping times, rather than simply between 11pm and 7am. To arrive at a reasonably reliable estimate, one should also have national data on distribution in the acoustic insulating properties of dwelling walls, taking bedroom window status (open/closed) into account. However, using a simplified model, one could generate point estimates of the prevalence of an effect using average sleeping time and

attenuation values, plus point estimates of the prevalence at above-average and below-average sleeping time and attenuation values, thus providing some insight into the spread of results associated with variations in these factors. Although such an exercise is in principle viable, the Committee is not in a position to perform the calculations itself.

3.5.3 *Health and well-being*

The Committee has concluded that there is sufficient evidence that exposure to night-time noise during the sleep period reduces sleep quality and general well-being. Furthermore, there is limited evidence of a causal association between exposure and impaired social contacts and concentration, increased risk of developing certain medical conditions, and premature mortality due to fatal occupational accidents. This conclusion is based upon assessment of research data regarding various effect parameters. The parameters in question are interrelated; for example, difficulty getting to sleep and staying asleep is closely related to diminished perceived sleep quality (all three effect parameters for sleep quality). Consequently, if one calculated the prevalence of each effect parameter separately (supposing that were possible), and aggregated the figures, one would arrive at an overestimate of the consequences of exposure to night-time noise. The Committee has therefore chosen to base its estimates of the prevalence of diminished sleep quality and general well-being on self-reported high sleep disturbance data. Where this parameter is concerned, exposure-effect relationships have been established for noise from road, rail and air traffic. Since there is only limited evidence that night-time noise can lead to impaired social contacts and concentration, hypertension and premature mortality due to fatal occupational accidents, and little is known about the possible exposure-effect relationships, no estimate can be made of the prevalence of these effects. The Committee has, however, worked out a figure for the prevalence of insomnia, but would emphasise that this figure, like that for self-reported high sleep disturbance, is merely an indicative estimate. For this reason, the estimate is couched in very general terms.

The estimates have been made using *Lnight* values for the year 2003 provided by the RIVM; see Annex G. The data used reflects the annual burdens on dwellings, as associated with road, rail and air traffic collectively (cumulative noise exposure). By combining this information with what is known about the exposure-effect relationships for self-reported high sleep disturbance by road traffic noise[97,98] (see Figure 12)* and insomnia[103], the Committee has been able to estimate the increase in the prevalence

* The estimates are based on road traffic, as in the Netherlands night-time noise exposure to road traffic noise is much higher than that to air and rail traffic noise. Furthermore, using the separate noise sources would lead to overestimating the total self-reported high sleep disturbance.

within the Dutch population of the two effects that was attributable to night-time traffic noise in 2003. The results are presented in Table 8.

Table 8 Rough estimate of the prevalence within the adult Dutch population (12.5 million people) of high sleep disturbance and insomnia attributable to night-time traffic noise in 2003.

Effect	Prevalence band[a]
Self-reported high sleep disturbance	6
Insomnia	5
Ratio between insomnia and self-reported high sleep disturbance	2%

[a] Prevalence bands: band 0: 0-1 person, band 1: 1-10 people, band 2: 10-100 people, band 3: 100-1000 people, band 4: 1000-10 000 people, band 5: 10 000-100 000 people, band 6: 100 000- 1 000 000 people.

As indicated in Table 8, the prevalence of noise-related self-reported high sleep disturbance among adults in the Netherlands falls in band 6 (100,000 to a million adults). The prevalence of noise-related insomnia is estimated to be significantly lower.

For the year 2000, the RIVM estimated separate *Lnight* values for the noise exposures associated with road, rail and air traffic noise in the Netherlands[15]. On the basis of these figures, it has been estimated that, in 2000, the prevalence of noise-related self-reported high sleep disturbance among adults in the Netherlands, as attributable to each of these three sources, fell in band 6 (more than 100,000 adults). The number of adults with high sleep disturbance by road traffic noise will have been between two and four times higher than the numbers able to report such disturbance by rail or air traffic noise. The prevalence of insomnia attributable to either road or rail traffic noise was in each case estimated to have been in band 4 (between one thousand and ten thousand people), while that attributable to aviation noise (calculated on the basis of data on the noise exposure in the general vicinity of Schiphol) was estimated to have been in band 3 (between a hundred and a thousand people).

3.5.4 *Disease burden*

In recent years, there has been considerable focus on quantifying the collective disease burden attributable to environmental factors. One initiative in this area has been the introduction of the *disability adjusted life year* (DALY)[32,34] as a unit of measurement; see also subsection 2.3.3. In response to questions posed by the State Secretary for Housing Spatial Planning and the Environment, the Health Council is to prepare a separate advisory report on the issues associated with the use of DALYs[38].

In order to quantify a disease burden, it is necessary to know how many people experience a given effect and for how long, as well as how serious the effect is. In its prevalence calculations described above, the Committee concentrated on self-reported high sleep disturbance and insomnia, in relation to which estimates were made of the numbers of people affected and for how long. To calculate the associated disease burdens, the Committee has adopted the weighting score of 0.17 ascribed to insomnia by Stolk *et al*[37], even though this figure was defined for a different purpose. In the context of seeking to put a figure on the disease burden associated with sleep disturbance[32], De Hollander suggested weighting factors of between 0.01 and 0.1, but indicated that further study was desirable.

On the basis of the available data, the Committee has concluded that the best estimate of the disease burden associated with high sleep disturbance by night-time traffic noise in the Netherlands is several tens of thousands of DALYs. The corresponding figure for insomnia is certainly considerably lower. These estimates suggest that, through its influence on sleep, night-time traffic noise accounts for an important part of the overall effect that the physical environment has on public health[32,104].

By means of disease burden calculations of this kind, the effects of night-time traffic noise on health and well-being can be compared with the effects of other factors. However, the Committee wishes to emphasise that a cautious approach should be taken, since there is considerable uncertainly about many of the estimates.

Chapter 4

Acoustic considerations

Night-time noise in the domestic environment almost always consists of a combination of separate noise events, with the exception of certain forms of industrial noise. In section 4.1, the Committee considers how such noise events combine to create an overall noise exposure over the course of a night.

Noises come in many different forms, from a low rumble to a soprano's top C, from a steady whisper to a sudden bang, from a murmur to a squeak or a grating sound. It seems reasonable to assume that the nature of a noise influences its effect. The question is, is it possible to define an exposure-effect relationship in a way that takes account of the influential characteristics of a noise, for example by applying adjustment factors to the exposure or noise data. In the 1997 advisory report *Assessing Noise Exposure for Public Health Purposes*, a Health Council Committee looked at this issue in detail (see Annex F for a summary)[8]. In section 4.2, the Committee considers the content of that report.

In the chapter's final section (4.3), the efficiency and effectiveness of domestic insulation as a means of reducing the influence of noise on sleep are examined.

4.1 The combination of noise events and acute effects

4.1.1 *The combination of noise events*

Where night-time environmental noise involving individually distinguishable noise events is concerned, *Lnight* is a so-called 'exponential summation of the *SEL* values of the constituent events*.

A given *Lnight* value is a unique specification of the number of noise events with a certain *SEL value*. Since, where a particular type of noise (such as a train or aeroplane passage) is concerned, there is a very high correlation is between the *SEL* and the maximum level of a noise event (*LAmax*), a given *Lnight* value also specifies the number of noise events with a certain *LAmax* value. For example, an *Lnight* of 35 dB(A) is the result of *one noise event per year* with an *SEL* of approximately 105 dB(A), *one noise event per night* (every night) with an *SEL* of approximately 80 dB(A) or *hundred noise events per night* (every night) with an *SEL* of approximately 60 dB(A).

4.1.2 *Lnight and effects*

It follows that, at least where the above-mentioned acute effects of exposure to night-time noise are concerned, the consequences associated with a given *Lnight* value may vary. Generally speaking, the sum of all acute effects (over a year, since *Lnight* is an annual average) in a situation characterised by a small number of high-intensity events is less than in a situation characterised by numerous events whose intensity is above the effect threshold but nevertheless comparatively low. The least favourable situation (that involving the most acute effects per year) would be a series of events with *SEL* values 4 to 5 dB(A) above the observation threshold for the effect in question[97,105,106]. For subject-registered awakening by aircraft noise, for example, the worst-case scenario involves all aircraft passages having an *indoor SEL* (*SEL_i*) of approximately 60 dB(A), whereas the worst situation for increased probability of acute motility would involve all passages having an *SEL_i* of approximately 45 dB(A). In other words, at a given *Lnight_i*, the characteristics of the least favourable situation depend on which acute effect one is concerned with.

In Table 6, the Committee indicated that long-term exposure to night-time noise when sleeping leads to an accumulation of acute effects indicative of a negative influence on health and well-being. Where the overall effect of exposure to night-time noise

* The points made in this section relate to both outdoor and indoor noise levels (although the latter are expressed in units that have the suffix '_i'). For definitions of the acoustic variables, see table 1.