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Review of Evidence Relating to Environmental Noise Exposure and Specific Health Outcomes in the context of the Interdepartmental Group on Costs and Benefits (ICGB(N): WP4

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1 Overview

1.1.1 This report sets out the methodology and findings of the systematic reviews undertaken by Arup to inform the Review of Evidence Relating to Environmental Noise Exposure and Specific Health Outcomes in the context of the ICGB(N): WP4.

1.1.2 Systematic review methodologies have been used to identify, screen, and review recently published evidence, following the general guidance methodology for systematic reviews as set out by the Cochrane Collaboration (Cochrane Collaboration 2011).

1.1.3 The methodology used in the project mirrors that used in the recent World Health Organization's (WHO) systematic reviews undertaken for the WHO Environmental Guidelines for the European Region (WHO 2018), where possible (Clark & Paunović, 2018a, 2018b; Nieuwenhuijsen, Ristovska, & Dadvand, 2017).

2 Key stages of the systematic review process

2.1.1 The current guidance methodology for systematic reviews, as set out by the Cochrane Collaboration, specifies the following stages for systematic reviews:

- Defining the review question and developing criteria for including studies;
- Searching for studies;
- Selecting studies and collecting data;
- Assessing risk of bias in included studies;
- Analysing data and undertaking meta-analysis;
- Presenting results and summary of findings tables; and
- Interpreting results and drawing conclusions.

2.1.2 The following sections set out how each of these stages have been addressed in this project.

Defining the review question and developing criteria for including studies

2.1.3 Using a systematic review methodology the review question for each systematic review was structured using the PICO (Participants,

Interventions, Comparisons and Outcomes) approach. This means that the review question should specify the types of population (participants), types of interventions (and comparisons), and the types of outcomes that are of interest. The review question, with the additional specification of types of study that will be included, form the basis of the pre-specified eligibility criteria for the review. For this project the review question is to

"assess the strength of the association between exposure to environmental noise and cognition; dementia and other neurodegenerative diseases; mental health, quality of life and wellbeing; birth and reproductive outcomes; and cancer."

2.1.4 This question has been examined for the general population in community and residential settings but evidence for effects on sub-groups or vulnerable groups in the population has been included, where available. Each outcome has been broadly defined to capture the available evidence and studies identified will use a standardised outcome.

2.2 Searching for studies

2.2.1 The review conducted searches of electronic databases for individual study papers. Given the limited time-frame available the review has searched two key databases:

- PubMed
- Science Direct

2.2.2 Based on knowledge and experience, it was felt that that these databases would identify the appropriate papers. Whilst typically a systematic review might search a greater number of databases, for this project two databases have been chosen to strike a balance with the timing needs of the project.

2.2.3 Grey literature has not been searched systematically due to project time constraints but relevant national surveys, such as SoNA 2014[1] have been included. The authors have also drawn on existing knowledge to add any relevant known journal or conference papers that were not identified by the database search. However, conference

[1] Survey of Noise Attitudes 2014 (CAP1506). Civil Aviation Authority (2017).

proceedings have not been systematically searched. For each health outcome, the reference lists of papers identified were additionally checked to identify any further relevant papers.

Scope of the review

2.2.4 The systematic reviews for each of the health outcomes were carried out for the time-periods shown in Table 1 based on the publication end-dates of the existing WHO reviews (mental health, cognition, birth and reproductive outcomes) or for the last four years (since 2014 – the date of the last ICGB(N) review) where existing reviews were not available (Dementia and other neurodegenerative diseases, Cancer).

Table 1: Summary of health outcomes and temporal scope for the systematic review

WP2: health outcome	**Temporal scope of review**
A: Cognition	June 2015 to March 2019
B: Dementia and other neurodegenerative diseases	January 2014 to March 2019
C: Mental health, quality of life and wellbeing	October 2015 to March 2019
D: Birth and reproductive outcomes[2]	January 2017 to March 2019
E: Cancer	January 2014 to March 2019

2.2.5 The search terms used have been based upon those used in the previous WHO systematic reviews on these health topics where available (Clark & Paunović, 2018a, 2018b; Nieuwenhuijsen et al., 2017). For dementia and other neurodegenerative diseases (health outcome B) and cancer (health outcome E) which were not included for the WHO work, we set up search terms using key words. The key words included are listed in 10.7.1.

2.2.6 The searches were undertaken for the following environmental noise sources (covering a range of noise metrics):

- Road;
- Rail;
- Aircraft;

[2] Defra request that this includes infertility as well as reproductive outcomes.

- Windfarms;
- Industry;
- Noise from building services equipment including ground and air source heat pumps;
- Neighbour noise; and
- Neighbourhood noise.

2.2.7 Papers examining other types of noise exposure, such as occupational noise or hospital noise were excluded. Papers that did not characterise noise using established methods, either measurement or modelling were not included in the review (e.g. studies that use distance to roads as a proxy for noise exposure were excluded).

2.2.8 Papers were sought that used epidemiological methods, including survey, case-control studies and cohort studies. Following the WHO methodology, experimental studies were excluded: this has particular relevance to the search for cognition where experimental studies are more commonly used.

2.3 Data screening

2.3.1 For each health outcome, the initial database searches were reviewed by two reviewers independently. The titles and abstracts of the papers identified were reviewed. Following this, the full-text of the papers was retrieved and reviewed for compliance with the eligibility criteria.

2.3.2 The eligibility criteria matched those used by the WHO systematic reviews, covering the aspects listed below. Papers which failed to meet any one of the (PECO[3]) inclusion criteria or which met one of the exclusion criteria were excluded from the review.

- **Population:** the inclusion criteria are studies of the general population or specific sub-groups of the population in settings (residences, public venues, educational facilities).
- **Exposure:** the inclusion criteria are exposure to high levels of environmental noise from the sources specified above. Included studies will either measure or calculate noise exposure levels expressed in decibel

[3] Population, Exposure, Comparator, Outcome)

values at an appropriate location for the study participants (e.g. home, school). Where calculated levels are available for transportation noise, they will reflect the use of roads, railways lines and flight routes. Exclusion criteria include studies using distance to source as a proxy for noise exposure and studies using subjective ratings of noise exposure (including noise annoyance) as a proxy for noise exposure.

- **Comparator:** the inclusion criteria are that the study has a comparator group with no noise exposure or a lower level of noise exposure.
- **Assessment of outcome:** the inclusion criteria are that the outcome data comes from medical records or interview or cognitive testing using a known scale or validated assessment method or that the outcome is self-reported from a questionnaire.

2.3.3 Where differences of opinion arose between the two independent reviews relating to study inclusion, these were discussed within the team and agreement reached.

2.3.4 Papers were identified for inclusion in the systematic review regardless of the study findings, i.e. all papers, regardless of whether they find a significant positive or negative association between environmental noise and the health outcome or whether they find no effect go forward for review.

Data extraction

2.3.5 Following screening of papers to be included in the review data extraction of the full-text papers was undertaken. The data extraction tables mirror those used in the recent WHO systematic reviews. Each study screened into the review was examined and the following information noted (see Annex 8: Extraction tables):

- Study design –cross-sectional, longitudinal, intervention study; and whether the study is an ecological, case-control, or a cohort study.
- Population – general population in settings (dwellings, public venues, educational facilities), response rate and other selection/bias factors;
- Exposure – how exposure to high levels of environmental noise was defined, for which noise sources, the noise metric used, and whether noise was modelled or measured;
- Comparator – what was the highest noise exposure group compared to – a group with no noise exposure or lower levels of noise exposure or does the study provide an exposure-response relationship;
- Confounding – which confounding factors were the analyses adjusted for;

- Outcomes – how was the outcome assessed, which measure, is it a standardised measure; and
- Findings – type of analyses undertaken, sample size relating to the effect size, expressed as effect per dB if possible' and
- Other comments – anything to note re. the study quality or whether it does not adjust for important confounders.

2.3.6 For each paper excluded at the data extraction stage a reason for the exclusion has been provided (see Annex 6: Excluded papers).

2.3.7 Each paper was assessed for the following types of bias (**Stage 1** of the assessment):

- Noise exposure assessment leading to information bias: evaluates whether the paper uses established noise metrics in dB; the time-frame of the noise measurements; the quality of the noise modelling;
- Bias due to confounding: evaluates whether the study used matching or adjustment in the analysis for potential confounding factors, such as socioeconomic status, which can influence both noise exposure and cognitive and health outcomes;
- Bias due to the selection of participants: evaluates whether the participants were randomly sampled from a known population and whether the response rate was higher than 60%. For longitudinal and intervention studies consideration will also be given to drop-out rates;
- Outcome assessment leading to information bias I: whether the cognitive or health outcome is objectively measured using a known scale or validated measure;
- Outcome assessment leading to information bias II: whether the assessment is blinded for exposure information in the cohort, i.e. is the assessment undertaken by someone who is unaware of the participant's noise exposure?

2.3.8 Ratings on these types of bias are low bias, unclear or high bias. Bias was noted as present if a paper failed to include or report this information. This is important as many studies fail to report a response rate for their study, which results in the study being assigned a rating as 'unclear' for bias due to the selection of participants.

2.3.9 Annexes 1-5 summarise the bias ratings for each individual study included in the review (**Stage 1**).

Analysing data and undertaking meta-analysis;

2.3.10 Previous reviews of these cognitive and health outcomes have struggled to identify enough papers to warrant the use of meta-analysis and have also identified problems of using meta-analysis when the outcome measures vary greatly across the studies e.g. for cognition and mental health and wellbeing (Clark & Paunović, 2018a, 2018b). Instead, a narrative review of the evidence was undertaken. A narrative approach will enable comparison with the evidence from the recent WHO systematic reviews. The narrative review considers the evidence for each noise source separately in relation to the range of outcomes identified for a specific health or cognitive outcome.

Interpreting results and drawing conclusions.

2.3.11 The GRADE methodology (Guyatt et al., 2008) recommended by the Cochrane Collaboration (Cochrane Collaboration, 2011), and modified for use in the WHO Environmental Noise Guidelines for the European Region (WHO, 2018) was used to interpret the body of evidence for each noise source and outcome.

2.3.12 The GRADE methodology is **not** used to rate individual studies within the body of evidence but is used to rate the overall quality of evidence available for a specific environmental noise source and health outcome – that is all of the studies available, regardless of whether they find a significant statistical effect of environmental noise on a specific health outcome or not. The GRADE methodology rates the quality of the evidence as high, medium, low or very low. The GRADE assessment has been undertaken individually for each environmental noise and health outcome where evidence is available, even if only one study is available. The following text describes the GRADE rating process – referred to as **Stage 2** and **Stage 3** of the assessment.

2.3.13 **Stage 2:** As for the WHO systematic reviews, the review has used an adapted GRADE methodology where the highest quality of evidence for environmental noise effects on cognition and health was assigned to longitudinal or intervention study evidence (Clark & Paunović, 2018b). The GRADE methodology traditionally (unadapted) assigns high quality evidence only to evidence from studies of a randomised control study design but this is not appropriate for studies of

environmental noise exposure where exposure is never randomised. In terms of Stage 2 of the assessment, this means that:

- If any of the evidence available is from a longitudinal or intervention study then the initial assessment is given as 'high quality'.
- If the evidence available is restricted to cross-sectional studies then the initial assessment is given as 'low quality'.

2.3.14 **Stage 3:** The GRADE methodology allows for initial evidence ratings to be further upgraded or downgraded according to specific criteria (see Figure 1). Upgrades can be made based on the availability of evidence for an exposure-response relationship between noise and the outcome; the magnitude of the relative risk being >2; or there being evidence for an effect despite of confounding working towards the null. Unfortunately, it is not possible to assess the magnitude of the relative risk or the exposure-response relationship when undertaking a narrative review as these assessments require the statistical outcome from meta-analyses. Upgrades for confounding are very rarely made and no upgrading of the evidence for this factor has taken place in this review.

2.3.15 Downgrades can be made based on most of the studies being of low quality (study design) as identified by the individual ratings of bias undertaken in Stage 1 of the process; inconsistent findings between studies (inconsistency); studies not comparing the same outcomes or populations (indirectness); effect estimate confidence interval containing 25% harm or benefit (precision); or publication bias, as assessed by a funnel plot. Unfortunately, it is not possible to assess

precision and publication bias when undertaking a narrative review as these also require statistical outputs.

Table 2 Further description of the upgrading and downgrading process for the GRADE Methodology.

	No downgrade	Downgrade
Study design	If most of the studies have been rated as having 'low bias' the quality of the evidence will not be downgraded.	If many or several of the studies have been rated as having uncertain bias or 'high bias' the quality of the evidence will be downgraded.
Inconsistency	If the findings of most of the studies agree that there is or is not an effect of environmental noise on the health outcome the quality of the evidence will not be downgraded.	If the findings of the studies are mixed in terms of whether there is or is not an effect of environmental noise on the health outcome, the quality of the evidence will be downgraded. If there is only one study available then consistency cannot be assessed and the evidence will be downgraded.
Indirectness	If most of the studies are comparable in terms of PECO (populations, exposure, comparator, and outcome) the quality of the evidence will not be downgraded.	If some of the studies are not comparable in terms of PECO (populations, exposure, comparator, and outcome) the quality of the evidence will be downgraded.
Precision	Not rated for narrative review as needs statistical analysis.	Not rated for narrative review as needs statistical analysis.
Publication bias	Not rated for narrative review as need to compute funnel plot.	Not rated for narrative review as need to compute funnel plot.
	No upgrade	**Upgrade**
Magnitude of effect	Not rated for narrative review as needs statistical analysis.	Not rated for narrative review as needs statistical analysis.
Plausible confounding	If the studies available within the body of evidence fail to adjust for all plausible confounders, then the evidence will not be upgraded.	If the evidence across the studies suggests that all plausible confounders have been accounted for, then the evidence will be upgraded.
Dose-response gradient	Not rated for narrative review as needs statistical analysis.	Not rated for narrative review as needs statistical analysis.

2.3.16 When used in studies of environmental noise and health, the GRADE methodology often results in downgrading of the evidence and very rarely in upgrading of the evidence. Several reasons for this are described below.

- There are often inconsistent findings across the body of evidence, e.g. the evidence is often a mix of studies that do and do not show an association, which will result in downgrading. This issue is often seen where there are a very limited number of studies available for a noise source and a health outcome but can also be seen where there are a larger number of studies, as the likelihood of inconsistency increases the greater the number of studies that are available. If only one study is available for a specific noise source and a health outcome then consistency cannot be assessed and the evidence is downgraded (this matches the approach used in the WHO systematic reviews). Across the review, there are very few instances where the quality of the evidence does not get downgraded for inconsistency, perhaps reflecting a weakness of the GRADE process when applied to epidemiological rather than clinical research studies.

- Whilst the assessment of the overall quality of evidence reflects the strengths and weaknesses introduced by inclusion of all the studies identified in the search, the weaknesses can end up carrying a greater weight in the assessment. The inclusion of less methodologically robust studies can weaken the assessment of the quality of the strength of the evidence by impacting on several factors, simultaneously. For example, if there are four studies identified, one of which is longitudinal and three of which are cross-sectional the initial rating would be of 'high quality evidence'. However, if two or three of the studies identified all have 'unclear or high bias' that will result in a downgrading, to 'moderate quality'. If the four studies also differ in whether they show an effect or not, that will result in a further downgrading to 'low quality'. If the four studies or some of the studies also differ in terms of PECO, that will result in a further downgrade to 'very low quality'. If methodologically weaker studies are included within the body of evidence, it does not really matter how methodologically robust the 'best' study is, as the other studies will result in a downgrading of the evidence.

- In terms of upgrading the evidence, whilst recent epidemiological studies typically adjust for a wide-range of relevant confounders and covariates, it can be very difficult conclude with confidence that

adjustment for further factors may not alter the effect. It is also worth noting, some study designs by default adjust for a limited number of covariates and confounders. For example, ecological studies such as a study of hospital admissions within an entire population usually cannot adjust for relevant socioeconomic or other health-related covariates at the individual level: instead, they often only adjust for area-level socioeconomic and other health-related covariates, which means that confounding cannot be ruled out. Often within the field of noise and health it is also not possible to undertake meta-analyses of data given variation in outcome measures used, which means that factors such as exposure-response relationship and magnitude of effect cannot be assessed, limiting the possibilities for upgrading the evidence.

2.3.17 The GRADE methodology is accompanied by a statement as to whether the body of evidence generally suggests there is an effect of environmental noise on the health outcome or if there is no effect. Drawing on the approach of previous ICGB(N) reports, where individual studies have carried weight in terms of establishing whether there is or is not an effect of noise on a health outcome, in this report, taking a precautionary approach an 'effect' has been identified even where there is only one study available within the body of evidence that shows an association. This approach may result in an over-statement of whether there is an effect or not as it ignores consistency across the available evidence.

2.3.18 Summary tables illustrating the GRADE methodology for each noise source and outcome have been provided, clearly illustrating the initial assessment and any downgrading[4] as relevant, along with the final assessment summaries (see Annexes 1-5).

[4] No upgrading of the evidence was undertaken, so this is not specified in each of the summary tables.

Figure 1 Description of the GRADE assessment and how the quality of the body of evidence for a health outcome can be downgraded or upgraded

Downgrade evidence if present	**Study limitations**	**Inconsistency of results**	**Indirectness of evidence**	**Imprecision of effect estimate**	**Publication bias**
	Any methodological limitations or flaws?	How much variation is there between studies (e.g. direction of effect or size of the estimate)?	Are the effects applicable for the whole population and across relevant outcomes?	Is the sample large enough to calculate a precise effect estimate? How wide are the confidence intervals?	Are all studies of the effect published – even those with null findings?
Upgrade if present	**Magnitude of effect**	**Plausible confounding**	**Dose-response gradient**		
	Do the studies yield large estimates of the magnitude of an effect?	Have all plausible confounding factors been accounted for?	Does the effect increase as exposure increases?		

3 Results for mental health, wellbeing and quality of life

3.1.1 The systematic review identified 29 studies of associations of environmental noise on mental health, wellbeing and quality of life (Dreger, Meyer, Fromme, & Bolte, 2015; A. Dzhambov, Hartig, Markevych, Tilov, & Dimitrova, 2018; A. Dzhambov, Tilov, Markevych, & Dimitrova, 2017; A. M. Dzhambov, I. Markevych, T. Hartig, et al., 2018; A. M. Dzhambov, I. Markevych, B. Tilov, et al., 2018; Feder et al., 2015; Gascon et al., 2018; Generaal, Timmermans, Dekkers, Smit, & Penninx, 2019; Hammersen, Niemann, & Hoebel, 2016; Kamimura et al., 2017; Klompmaker et al., 2019; Lawton & Fujiwara, 2016; Leijssen et al., 2019; Lim et al., 2018; Ma, Li, Kwan, & Chai, 2018; Oiamo, Luginaah, & Baxter, 2015; Okokon et al., 2018; Pun, Manjourides, & Suh, 2019; Seidler et al., 2017; Skrzypek, Kowalska, Czech, Niewiadomska, & Zejda, 2017; Taskaya, 2018; Van Aart et al., 2018; Wallas et al., 2018; Welch, Dirks, Shepherd, & McBride, 2018; Weyde et al., 2017; Wright, Newell, Maguire, & O'Reilly, 2018; Xiao, Li, & Zhang, 2016; Zijlema, Morley, Stolk, & Rosmalen, 2015; Zock et al., 2018). Two additional relevant studies were identified from the search conducted for cognition (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016), and birth outcomes (He et al., 2019), respectively. The national Survey of Noise Attitudes 2014 (Civil Aviation Authority, 2017) was also added, along with a study of the NORAH study which had not been identified from the database searches (Klatte et al., 2016). Another study was identified from the recent Internoise 2019 conference (Zijlema, De Kluizenaar, Van Kamp, & Hartman, 2019) giving a total of 34 studies for consideration. Ten studies were excluded as they did not directly measure noise (Dreger et al., 2015; Hammersen et al., 2016; Kamimura et al., 2017; Ma et al., 2018; Pun et al., 2019; Skrzypek et al., 2017; Taskaya, 2018; Xiao et al., 2016), or because no associations between noise exposure and mental health were reported (A. Dzhambov et al., 2018; Gascon et al., 2018). This left 24 studies for inclusion in the review. Figure 2 summarises the review process.

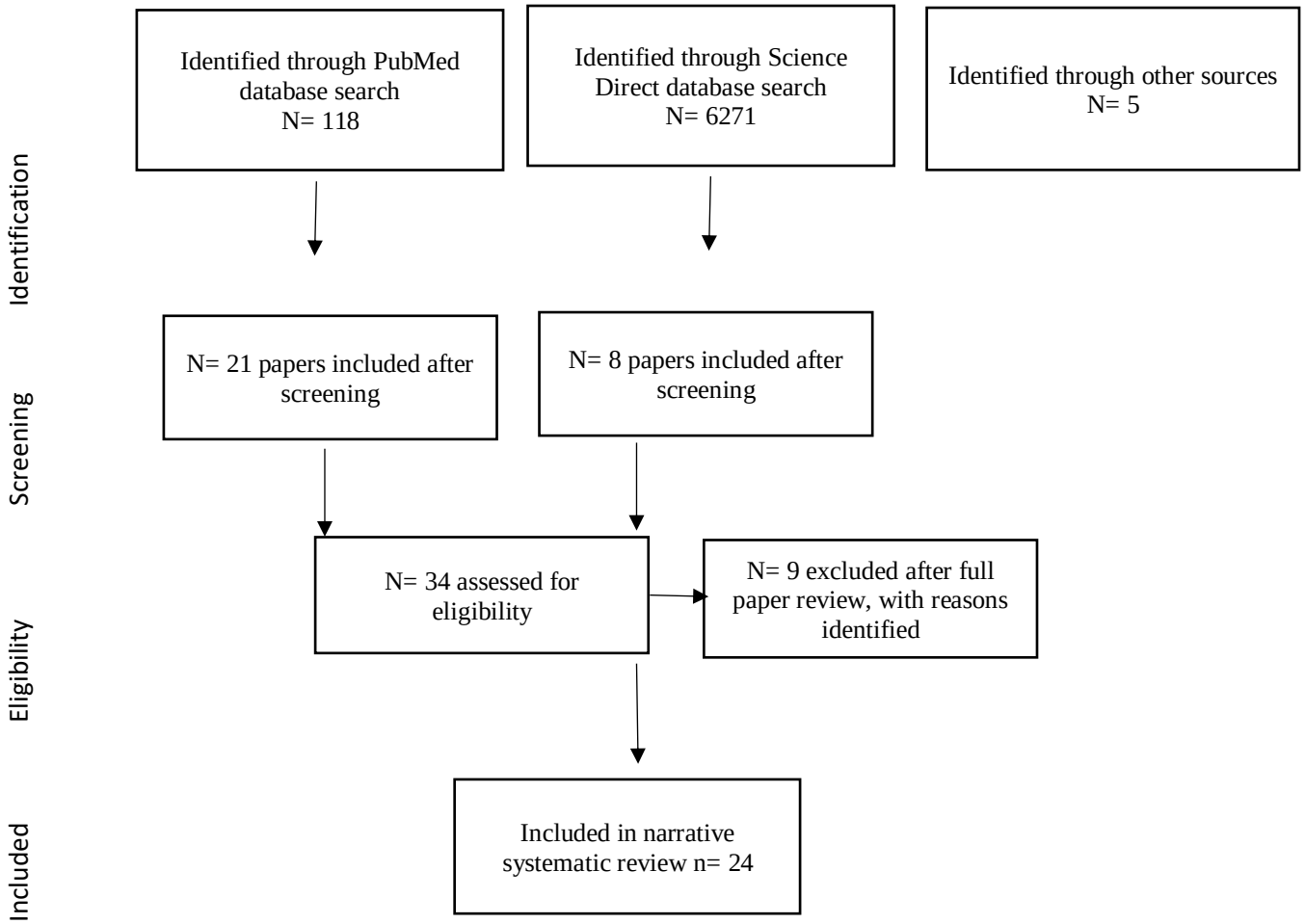
3.1.2 The studies were conducted in Belgium, Bulgaria, Canada, Finland, Germany, the Netherlands, New Zealand, Norway, South Korea, Sweden and the United Kingdom. Most studies examined road

traffic noise, but some studies also examined railway noise and/or aircraft noise. One study of wind turbine noise was identified. The evidence was from longitudinal cohort studies, as well as cross-sectional studies. The studies of adult mental health and wellbeing examined a range of outcomes including post-partum depression, medical diagnoses of depression and anxiety, medication use, symptom scales of mental health, wellbeing, and quality of life. For children the outcomes included the Strengths and Difficulties questionnaire (Goodman, 1997), as well as symptom scores or diagnoses for inattention/ADHD[5] and self or parental reports of wellbeing.

3.1.3 The detailed data extraction for these studies is shown in Table 42 Annex 8: Extraction tables. Few of the studies were individually all rated as having low bias (see Table 42 Annex 8: Extraction tables): for many studies the rating for bias was unclear or high bias. This was often because of low response rates for the study or response rates not being clearly stated.

[5] Attention Deficit Hyperactivity Disorder.

Figure 2 Flow chart showing the review process for the quality of life, wellbeing and mental health papers



3.1.4 The following GRADE assessment of the strength of the evidence is organised under the following headings to enable comparison with the WHO evidence review (Clark & Paunović, 2018a):

- Self-reported quality of life or health
- Self-reported depression, anxiety and psychological symptoms[6]
- Interview measures of depressive and anxiety disorders

[6] Self-reported depression, anxiety and psychological symptoms are assessed using established scales of symptoms; this is differentiated from self-reports of health conditions such as having been diagnosed with depression, which would fall under the heading of self-reported quality of life or health in this assessment.

- Emotional and conduct disorders in children
- Hyperactivity
- Wellbeing (not assessed in WHO review)
- ADHD (not assessed in WHO review)

Self-reported quality of life or health

3.1.5 For aircraft noise, the national Survey of Noise Attitudes 2014 did not find an association between aircraft noise (LAeq 16h) and self-reported health (Civil Aviation Authority, 2017). Another study from the United Kingdom using Census data from around Belfast Airport failed to find an association between aircraft noise and self-reported mental health assessed as "an emotional, psychological or mental health condition (such as depression or schizophrenia)" (Wright et al., 2018). A New Zealand study found that aircraft noise exposure was associated with quality of life for residents but only for those who were noise sensitive (Welch et al., 2018). The NORAH study of primary school children found that aircraft noise exposure at school was associated with lower ratings of children's quality of life, as reported by their parents (Klatte et al., 2016).

3.1.6 A high-quality (rated as having low bias) study concluded that there was little support for an association between wind turbine noise and quality of life (Feder et al., 2015).

Self-reported depression, anxiety and psychological symptoms

3.1.7 Several studies of road traffic noise have not found associations with psychological symptoms assessed using the K-10 (Klompmaker et al., 2019) or the SCL-90 (Zijlema et al., 2015). One Canadian study found an association between road noise and psychological symptoms assessed by the SF-12 (Oiamo et al., 2015). A Dutch study found an association between road traffic noise and depressed mood, as assessed by the PHQ-9 but only for those exposed to >70dB LAeq 24h compared with 45-54dB LAeq 24h (Leijssen et al., 2019): however, this study also found a protective effect of road traffic noise exposure for depressed mood, with the odds being lower for those exposed to 60-64dB LAeq 24h compared with 45-54dB LAeq 24h. Three studies from a series of studies from Bulgaria

suggest that road traffic noise and residential noise[7] is associated with psychological symptoms, as reported using the GHQ-12 (General Health Questionnaire 12 item version) but only indirectly via effects on noise annoyance, neighbourhood restorative quality, social cohesion and physical activity (A. Dzhambov et al., 2017; A. M. Dzhambov, I. Markevych, T. Hartig, et al., 2018; A. M. Dzhambov, I. Markevych, B. Tilov, et al., 2018), however, these findings may be biased and limited by the sample size and use of convenience sampling.

3.1.8 One Dutch study of railway noise was identified which found an association with psychological symptoms assessed using the K-10 (Klompmaker et al., 2019).

Interview measures of depressive and anxiety disorders

3.1.9 The NORAH study demonstrated exposure-effect relationships for road traffic noise, aircraft noise and railway noise with medically reported diagnoses of depression (Seidler et al., 2017): however, the study failed to show an association for aircraft noise at higher levels and had low statistical power to assess higher levels of noise exposure. A Dutch study also supports a relationship between road traffic noise, aircraft noise and railway noise and diagnoses of depression and anxiety (Generaal et al., 2019), however, another Dutch study failed to show an association between road traffic noise or railway noise and diagnoses of depression and anxiety (Zock et al., 2018). A longitudinal study of pregnant women in Montreal followed up for 18 years found that residential noise estimates (predominantly road noise but also included aircraft noise and railway traffic) were associated with hospitalisations for depression or other mental disorders[8], with stronger associations seen for night-time than day-time noise exposure (He et al., 2019).

Emotional and conduct disorders in children

3.1.10 Three studies report the association between road traffic noise and emotional and conduct disorders in children (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, Lopez-Vicente, et al., 2016; Lim et al., 2018; Van Aart et al., 2018). However, the evidence is mixed

[7] Described as traffic sites, industrial sites, sites in residential and recreational areas. These studies are considered under road noise for this review.
[8] This included schizophrenia, bipolar disorder, anxiety-related, stress-related, and personality disorders.

with some studies suggesting no association between road traffic noise and the total difficulties score of the SDQ (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016) and the total behavioural difficulties scores from the Child Behaviour Checklist (Lim et al., 2018), although the latter study did not demonstrate the association for other measures of mental health including internalizing and externalizing scores. Another study found little evidence to support an association with total strengths and difficulties scores of the SDQ (Van Aart et al., 2018)[9].

Hyperactivity in children

3.1.11 Three studies examine the association between road traffic noise and hyperactivity (assessed as inattention/ADHD symptoms or SDQ hyperactivity scale) (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016; Van Aart et al., 2018; Weyde et al., 2017). Two of the studies suggest an effect of road traffic noise on inattention (Weyde et al., 2017) and ADHD symptoms (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016). However, another study suggested an inverse relationship between road traffic noise and hyperactivity: that is, as road traffic noise exposure increased hyperactivity scores decreased (Van Aart et al., 2018).

Cortisol in children

3.1.12 One Swedish study reported the association between road traffic noise and salivary cortisol, finding no association with road traffic noise exposure but an association with noise annoyance (Wallas et al., 2019).

Wellbeing

3.1.13 The NORAH study of primary school children found that aircraft noise exposure at school was associated with lower ratings of children's mental and physical wellbeing and wellbeing at school (Klatte et al., 2016).

3.1.14 The national Survey of Noise Attitudes 2014 failed to find associations between aircraft noise (LAeq 16h) and self-reported health or the Warwick Edinburgh Mental Wellbeing Scale, although it did find associations for these outcomes with noise annoyance

[9] This study reports on traffic noise – a combination of road and railway noise. For the review it is considered under road traffic noise.

(Civil Aviation Authority, 2017). A UK study using Census data for people living around 17 airports and the ONS measure of wellbeing, found that day-time aircraft noise was associated with wellbeing (Lawton & Fujiwara, 2016): no association was found between night-time aircraft noise exposure and wellbeing.

Medication intake for treatment of anxiety and depression

3.1.15 Two studies examined the association of road traffic noise on medication intake for the treatment of anxiety and depression (Klompmaker et al., 2019; Okokon et al., 2018). One study in Finland found no association between road traffic noise and use of anxiolytics or anti-depressants (Okokon et al., 2018). One Dutch study found an association between road traffic noise and anxiolytic use but not antidepressants (Klompmaker et al., 2019).

3.1.16 One Dutch study of railway noise and medication intake for the treatment of anxiety and depression was identified, which found no association for anxiolytic or antidepressant medication (Klompmaker et al., 2019).

3.2 GRADE assessment of self-reported quality of life or health

3.2.1 Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise on self-reported quality of life or health, we considered longitudinal or intervention studies the ideal study design. Four cross-sectional studies were available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for some of the evidence, as well as inconsistency and indirectness (Table 7).

- There is very low quality evidence for no effect of aircraft noise on self-reported quality of life or health.

3.2.2 For wind-turbine noise, one cross-sectional study was available, so the evidence was initially rated as low quality. This was further

downgraded to very low-quality given that inconsistency could not be assessed (Table 7).

• There is very low quality evidence for no effect of wind turbine noise on self-reported quality of life or health.

3.2.3 Evidence for the effects of other noise sources (including road traffic and railway noise) on self-reported quality of life or health was not available, so no GRADE assessment is provided for these sources.

3.3 GRADE assessment of self-reported depression, anxiety and psychological symptoms

3.3.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road noise on self-reported depression, anxiety and psychological symptoms, we considered longitudinal or intervention studies the ideal study design. Seven cross-sectional studies were available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence, as well as inconsistency as the findings differed across the studies (Table 8).

- There is very low quality evidence for no effect of road traffic noise on self-reported depression, anxiety and psychological symptoms.

3.3.2 Applying the GRADE framework to assess the quality of evidence across the available studies of railway noise on self-reported depression, anxiety and psychological symptoms, we considered longitudinal or intervention studies the ideal study design. One cross-sectional study was available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence, as well as being unable to assess inconsistency as only one study was available (Table 8).

- There is very low quality evidence for no effect of railway noise on self-reported depression, anxiety and psychological symptoms.

3.3.3 Evidence for the effects of other noise sources (including aircraft noise) on self-reported depression, anxiety and psychological

symptoms was not available, so no GRADE assessment is provided for these sources.

3.4 GRADE assessment of interview measures of depressive and anxiety disorders

3.4.1

Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise on interview measures of depressive and anxiety disorders, we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available, so the evidence was initially rated as high quality. This was downgraded to low quality given unclear bias for the evidence and inconsistent findings[10] (Table 9).

- There is low quality evidence for an effect of aircraft noise on interview measures of depressive and anxiety disorders.

3.4.2

Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on interview measures of depressive and anxiety disorders, we considered longitudinal or intervention studies the ideal study design. Two longitudinal studies were available, so the evidence was initially rated as high quality. This was downgraded to low quality given unclear bias for the evidence and inconsistent evidence across the studies (Table 9).

- There is low quality evidence for an effect of road traffic noise on interview measures of depressive and anxiety disorders.

3.4.3

Applying the GRADE framework to assess the quality of evidence across the available studies of railway noise on interview measures of depressive and anxiety disorders, we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available, so the evidence was initially rated as high quality. This was downgraded to low quality given unclear bias for the evidence and inconsistent evidence across the studies (Table 9).

- There is low quality evidence for an effect of railway noise on interview measures of depressive and anxiety disorders.

[10] Whilst the two studies both show an association, the NORAH study did not show an association at higher exposure levels, so this is considered inconsistent.

3.4.4 Evidence for effects of noise from other sources on interview measures of depressive and anxiety disorders was not available.

3.5 GRADE assessment for wellbeing

3.5.1 Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise on wellbeing, we considered longitudinal or intervention studies the ideal study design. Only cross-sectional evidence was available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence and inconsistent evidence across the studies (Table 10).

- There is very low quality evidence for an effect of aircraft noise on wellbeing.

3.5.2 Evidence for effects of noise from other sources on wellbeing was not available.

3.6 GRADE assessment for emotional and conduct disorders in children

3.6.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on emotional and conduct disorders in children, we considered longitudinal or intervention studies the ideal study design. Longitudinal studies were available, so the evidence was initially rated as high quality. This was downgraded to low quality given unclear bias for the evidence and inconsistent evidence across the studies (Table 11).

- There is low quality evidence for an effect of road traffic noise on emotional and conduct disorders in children.

3.6.2 Evidence for effects of noise from other sources on emotional and conduct disorders in children was not available.

3.7 GRADE assessment for hyperactivity in children

3.7.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on hyperactivity in children, we considered longitudinal or intervention studies the ideal

study design. Longitudinal studies were available, so the evidence was initially rated as high quality. This was downgraded to low quality given unclear bias for the evidence and inconsistent evidence across the studies (Table 12).

- There is low quality evidence for an effect of road traffic noise on hyperactivity in children.

3.7.2 Evidence for effects of noise from other sources on hyperactivity in children was not available.

3.8 GRADE assessment for cortisol in children

3.8.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on cortisol in children, we considered longitudinal or intervention studies the ideal study design. Only one cross-sectional study was available, so the evidence was initially rated as low quality. This was downgraded to low quality given unclear bias for the evidence and being unable to assess consistency of findings across the studies (Table 13).

- There is very low quality evidence for an effect of road traffic noise on cortisol in children.

3.8.2 Evidence for effects of noise from other sources on cortisol in children or in adults was not available.

3.9 GRADE assessment for medication intake for the treatment of anxiety and depression

3.9.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on medication intake for the treatment of anxiety and depression, we considered longitudinal or intervention studies the ideal study design. Only two cross-sectional studies were available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence and inconsistency of findings across the studies (Table 14).

- There is very low quality evidence for an effect of road traffic noise on medication intake for the treatment of anxiety and depression.

3.9.2 Applying the GRADE framework to assess the quality of evidence across the available studies of railway noise on medication intake for the treatment of anxiety and depression, we considered longitudinal or intervention studies the ideal study design. Only one cross-sectional study was available, so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence and being unable to assess inconsistency of findings across studies (Table 14).

- There is very low quality evidence for an effect of railway noise on medication intake for the treatment of anxiety and depression.

3.9.3 Evidence for effects of noise from other sources on medication intake for the treatment of anxiety and depression was not available.

3.10 GRADE assessment for ADHD in children

3.10.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on ADHD[11] in children, we considered longitudinal or intervention studies the ideal study design. One cross-sectional study was available (Zijlema et al., 2019), so the evidence was initially rated as low quality. This was downgraded to very low quality given unclear bias for the evidence and inconsistency of findings across the studies (Table 15).

- There is very low quality evidence for no effect of road traffic noise on ADHD in children.

3.10.2 Evidence for effects of noise from other sources on ADHD in children was not available.

3.11 Comparison of the review findings with the WHO review

3.11.1 The WHO review for mental health, wellbeing and quality of life covered the evidence from a 10-year period, whereas the current review covers a four-year period. It is therefore prudent to consider whether the strength of the evidence identified within the WHO review is informative over and above the conclusions of the current review, which only covers a more limited time-frame. The key

[11] The study examines diagnoses and symptoms of ADHD.

question is whether the studies identified in the current review would alter or strengthen the conclusions of the WHO review.

3.11.2 The conclusions regarding the strength of the evidence for the WHO (Clark & Paunović, 2018b) review are provided in Figure 3, Table 3, Table 4 and Table 5.

Figure 3 Summary of the strength of the evidence from the WHO review of mental health, wellbeing and quality of life

Clark & Paunovic 2018 – Mental health, wellbeing and quality of life

Method: The WHO review identified 29 papers using

- a systematic review search covering January 2005-October 2015

WHO conclusions regarding the strength of the evidence:

- For aircraft noise there was very low-quality evidence for no effect on self-reported quality of life or health and a harmful effect on medication intake for treatment of anxiety and depression and interview measures od depressive and anxiety disorders.
- For aircraft noise there was low quality evidence for no effect on emotional and conduct disorders in children and a harmful effect on hyperactivity.
- For road traffic noise there was low quality evidence for no effect on self-reported quality of life or health and very low quality evidence for no effect on medication intake for treatment of anxiety; depression and interview measures of depressive and anxiety disorders; and self-reported depression, anxiety and psychological symptoms.
- For road traffic noise there was moderate quality evidence for an effect on emotional and conduct disorders in children and a harmful effect on hyperactivity.
- For railway noise there was low quality evidence for a harmful effect on self-reported quality of life or health; moderate quality evidence for a harmful effect of emotional and conduct disorders in children; and moderate quality evidence for no effect on hyperactivity.

Research gaps & needs:

- Few studies of clinically significant mental health outcomes; few studies of railway noise exposure; and studies of large samples are needed.

3.11.3 The conclusions from the WHO review for aircraft noise and mental health, wellbeing and quality of life do not differ greatly in comparison with the conclusions of the current review (Table 3 Comparison of the strength of the evidence for the WHO 2018 and the current review for aircraft noise and mental health, wellbeing and quality of life. The current review was not able to reassess many of the outcomes for aircraft noise and mental health, wellbeing and quality of life because of a lack of studies.

3.11.4 The current review suggests that the conclusions for the effect of aircraft noise on interview measures of depressive and anxiety disorders could be updated, as the evidence now suggests that there is low quality evidence for a harmful effect. This difference is attributable to the publication of several longitudinal studies since the WHO review, and the conclusion of the current review should be considered to stand.

Table 3 Comparison of the strength of the evidence for the WHO 2018 and the current review for aircraft noise and mental health, wellbeing and quality of life.

Outcome	WHO Clark & Paunovic 2018	Current review
	Aircraft noise	
Self-reported quality of life or health	Very low quality – no effect	Very low quality – no effect*[12]
Medication intake for treatment of anxiety and depression	Very low quality – harmful effect	n.a.
Self-reported depression, anxiety and psychological symptoms	n.a.	n.a.
Interview measures of depressive and anxiety disorders	Very low quality – harmful effect	Low quality – harmful effect
Emotional and conduct disorders in children	Low quality – no effect	n.a.
Hyperactivity	Low quality – harmful effect	n.a.
Wellbeing	Not evaluated in the review	Very low quality – harmful effect
n.a. – no studies available to evaluate		

[12] A similar assessment of very low quality evidence for no effect of wind turbine noise on self-reported quality of life or health was also found in the current review. This was not found in the WHO review.

3.11.5 The conclusions from the WHO review for road traffic noise and mental health, wellbeing and quality of life do differ slightly in comparison with the conclusions of the current review (Table 4).

3.11.6 The WHO review concluded that there was very low quality evidence for no effect of road traffic noise on interview measures of depressive and anxiety disorders, whereas the current review suggests there is now low quality evidence for a harmful effect. This difference can be attributed to an increase in longitudinal evidence since the WHO review, and the conclusion of the current review should be considered to stand.

3.11.7 The WHO review concluded that there was very low quality evidence for no effect on medication intake for the treatment of anxiety and depression assessing three studies, whereas the current review suggests there is very low quality evidence for an effect assessing two studies. However, the evidence supporting an effect comes only from one study and the three studies in the WHO review did not find an effect[13]. Taken as a whole, the conclusion of the WHO review should be considered to stand until further evidence is forthcoming.

3.11.8 Both reviews concluded that there is very low quality evidence for no effect of road traffic noise on self-reported depression, anxiety and psychological symptoms.

3.11.9 The WHO review concluded that there was moderate quality evidence for a harmful effect of road traffic noise on emotional and conduct disorders in children and hyperactivity. The current review considers the evidence for these outcomes to be of low quality for a harmful effect, albeit based on far fewer studies. The conclusions of the WHO review should be considered to stand as the conclusion is drawn from a greater number of studies.

[13] With the exception of one study that found an effect in a sub-sample only.

Table 4 Comparison of the strength of the evidence for the WHO 2018 and the current review for road traffic noise and mental health, wellbeing and quality of life.

Outcome	WHO Clark & Paunovic 2018	Current review
	Road noise	
Self-reported quality of life or health	Low quality– no effect	n.a.
Medication intake for treatment of anxiety and depression	Very low quality– no effect	Very low quality – harmful effect
Self-reported depression, anxiety and psychological symptoms	Very low quality – no effect	Very low quality – no effect
Interview measures of depressive and anxiety disorders	Very low quality – no effect	Low quality – harmful effect
Emotional and conduct disorders in children	Moderate quality – harmful effect	Low quality – harmful effect
Hyperactivity in children	Moderate quality – harmful effect	Low quality – harmful effect
Cortisol in children	n.a.	Very low quality – harmful effect
Wellbeing	Not included in this review	n.a.
ADHD in children	Not included in this review	Very low quality – no effect
n.a. – no studies available to evaluate		

3.11.10 The conclusions from the WHO review for railway noise and mental health, wellbeing and quality of life are little changed by the findings of the current review (Table 5). The current review additionally suggests that there is low quality evidence for a harmful effect of railway noise on interview measures of depressive and anxiety disorders, which the WHO review did not assess due to lack of evidence. The WHO assessment for railway noise should be considered to stand, with the addition of the findings for interview measures of depressive and anxiety disorders and for medication intake for the treatment of anxiety and depression.

Table 5 Comparison of the strength of the evidence for the WHO 2018 and the current review for railway noise and mental health, wellbeing and quality of life.

Outcome	WHO Clark & Paunovic 2018	Current review
	Railway noise	
Self-reported quality of life or health	Low – harmful effect	n.a.
Medication intake for treatment of anxiety and depression	n.a.	Very low quality – harmful effect
Self-reported depression, anxiety and psychological symptoms	n.a.	Very low quality – no effect
Interview measures of depressive and anxiety disorders	n.a.	Low quality – harmful effect
Emotional and conduct disorders in children	Moderate quality – harmful effect	n.a.
Hyperactivity	Moderate quality – no effect	n.a.
Wellbeing	n.a.	n.a.
n.a. – no studies available to evaluate		

3.11.11 The current review is additionally able to conclude that there is very low quality evidence for no effect of wind turbine noise on self-reported quality of life or health which was not assessed in the WHO review.

4 Results for cancer

4.1.1 The systematic review identified eleven studies of associations of environmental noise on cancer (Andersen et al., 2018; Hegewald et al., 2017; Hvidtfeldt et al., 2019; James, Hart, Banay, & Laden, 2016; Roswall et al., 2018; Roswall et al., 2016; Roswall, Bidstrup, et al., 2017; Roswall et al., 2015; Roswall, Raaschou-Nielsen, et al., 2017; Sorensen et al., 2015; Sorensen, Ketzel, Overvad, Tjonneland, & Raaschou-Nielsen, 2014). Three studies were excluded after data extraction (Hvidtfeldt et al., 2019; James et al., 2016; Roswall et al., 2018) as they did not assess a cancer outcome per se or did not measure noise (Annex 6: Excluded papers). This left eight studies in the review.

4.1.2 Seven of these studies were conducted in Denmark, with six out of eight studies being from large Danish Diet, Health and Cancer longitudinal cohort study. The other studies were of a further Danish sample and a sample from Frankfurt, Germany.

4.1.3 The studies consider the effects of noise on the incidence of a number of types of cancer, including breast cancer, colorectal cancer, prostate cancer and Non-Hodgkin lymphoma, as well as sub-types for some of the cancers. Some evidence is available assessing cancer at the population level, using established markers such as all-cause mortality from cancer (that is, cancer mortality for all cancers combined). The studies were longitudinal prospective cohort studies or case control studies. Most studies examined road traffic noise, but some studies also considered railway noise or aircraft noise.

4.1.4 The detailed data extraction for these studies is shown in Table 43 Annex 8: Extraction tables. The studies were all individually rated as having low bias (see Table 16).

4.1.5 Overall, the evidence for an effect of environmental noise on cancer is mixed. There are few studies that examine railway noise. Studies have found no association between railway noise and colorectal cancer (Roswall, Raaschou-Nielsen, et al., 2017) or prostate cancer (Roswall et al., 2015) or breast cancer (Hegewald et al., 2017), although one study did find an association for estrogen negative

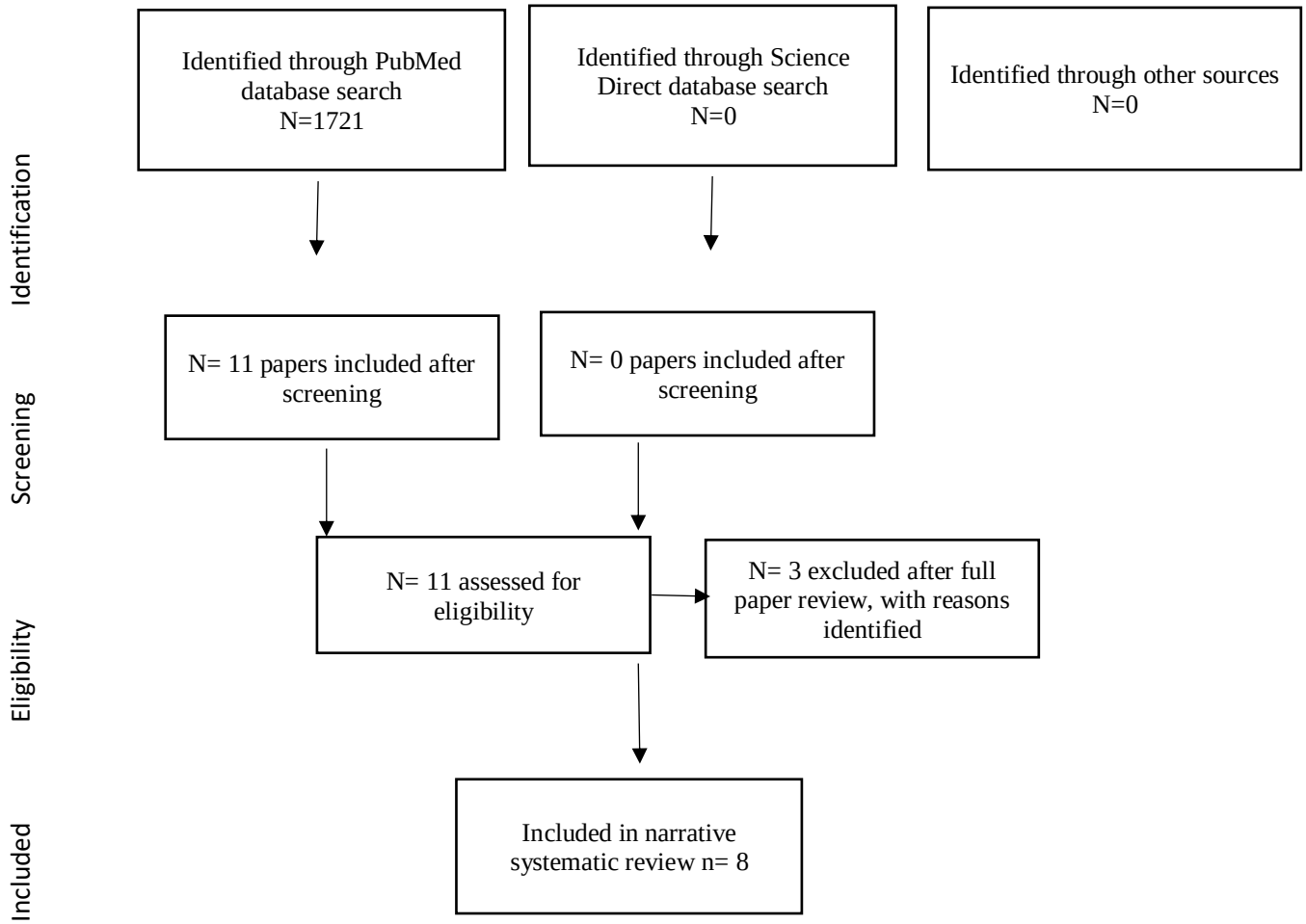
breast cancer but not for estrogen positive breast cancer (Sorensen et al., 2014).

4.1.6 For road traffic noise, four studies find no association with colorectal cancer (Roswall, Bidstrup, et al., 2017; Roswall, Raaschou-Nielsen, et al., 2017), breast cancer (Hegewald et al., 2017; Roswall et al., 2016), overall cancer mortality (Roswall, Bidstrup, et al., 2017) or prostate cancer (Roswall et al., 2015). One study finds an association between road traffic noise and breast cancer (Andersen et al., 2018), Another study also found an association between road traffic noise and Non-Hodgkin lymphoma (Sorensen et al., 2015). But some studies find an effect for a specific type of cancer, e.g. distal colon cancer but not proximal colon cancer (Roswall, Raaschou-Nielsen, et al., 2017) and estrogen negative breast cancer but not for estrogen positive breast cancer (Sorensen et al., 2014).

4.1.7 One study examines aircraft noise, finding an association with estrogen negative breast cancer but not estrogen positive breast cancer (Hegewald et al., 2017).

4.1.8 It may be worth exploring the application of meta-analysis to the evidence for cancer, to estimate the association of noise with cancer across the studies. However, a few more studies per source and cancer outcome may be needed before this would be useful.

Figure 4 - Flow chart showing the review process for the cancer papers



4.2 GRADE assessment –cancer mortality

4.2.1

Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise and cancer mortality we considered longitudinal or intervention studies the ideal study design. Two longitudinal studies were available (Roswall et al., 2016; Roswall, Bidstrup, et al., 2017), which examined overall cancer mortality as well as breast cancer specific mortality and colorectal cancer specific mortality, which we designated as high

quality. No reasons to downgrade the evidence were identified (Table 18).

- There is high quality evidence for no effect of road traffic noise on cancer mortality.

4.2.2 No studies of other noise sources and cancer mortality were identified.[14]

4.3 GRADE assessment – incidence of breast cancer

4.3.1 Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise on the incidence of breast cancer, we considered longitudinal or intervention studies the ideal study design. One study was longitudinal was available (Hegewald et al., 2017) which we designated as high quality. As only one study of aircraft noise and incidence of breast cancer was available we were unable to assess inconsistency or indirectness so the evidence was downgraded to low quality (Table 17).

- There is low quality evidence for an effect of aircraft noise on the incidence of breast cancer.

4.3.2 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on the incidence of breast cancer, we considered longitudinal or intervention studies the ideal study design. Three longitudinal studies were available (Andersen et al., 2018; Hegewald et al., 2017; Sorensen et al., 2014), so the evidence was designated as high quality. However, given inconsistency in findings across studies and the indirectness of the evidence (i.e. the effect was not seen for all breast cancer outcomes) the evidence was downgraded to low quality (Table 17).

- There is low quality evidence for an effect of road traffic noise on the incidence of breast cancer.

4.3.3 Applying the GRADE framework to assess the quality of evidence across the available studies of railway traffic noise on the incidence of breast cancer, we considered longitudinal or intervention studies the ideal study design. Two longitudinal studies were available (Hegewald et al., 2017; Sorensen et al., 2014), so the evidence was designated as high quality. However, given inconsistency in findings

[14] The Roswall, Bidstrup, et al., 2017 paper only assesses railway noise as a covariate for the association of road traffic noise on cancer mortality.

across studies and the indirectness of the evidence (i.e. the effect was not seen for all breast cancer outcomes) the evidence was downgraded to low quality (Table 17).

- There is low quality evidence for an effect of railway noise on the incidence of breast cancer.

4.4 GRADE assessment –incidence colorectal cancer

4.4.1

Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise and incidence of colorectal cancer we considered longitudinal or intervention studies the ideal study design. One longitudinal study available (Roswall, Raaschou-Nielsen, et al., 2017), which we designated as high quality. As only one study was available we were unable to assess inconsistency or indirectness so the evidence was downgraded to low quality (Table 19).

- There is low quality evidence for an effect of road traffic noise on the incidence of colorectal cancer.

4.4.2

Applying the GRADE framework to assess the quality of evidence across the available studies of railway noise and incidence of colorectal cancer we considered longitudinal or intervention studies the ideal study design. One longitudinal study available (Roswall, Raaschou-Nielsen, et al., 2017), which we designated as high quality. As only one study was available we were unable to assess inconsistency or indirectness so the evidence was downgraded to low quality (Table 19).

- There is low quality evidence for no effect of railway noise on the incidence of colorectal cancer.

4.4.3

No studies of other noise sources and the incidence of colorectal cancer were identified.

4.5 GRADE assessment –incidence prostate cancer

4.5.1

Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise and incidence of prostate cancer we considered longitudinal or intervention studies the ideal study design. One longitudinal study available (Roswall et al., 2015), which we designated as high quality. As only one study

was available we were unable to assess inconsistency or indirectness so the evidence was downgraded to low quality (Table 20).

- There is low quality evidence for no effect of road traffic noise on the incidence of prostate cancer.

4.5.2 Applying the GRADE framework to assess the quality of evidence across the available studies of railway noise and incidence of prostate cancer we considered longitudinal or intervention studies the ideal study design. One longitudinal study available (Roswall et al., 2015), which we designated as high quality. As only one study was available we were unable to assess inconsistency or indirectness, so the evidence was downgraded to low quality (Table 20).

- There is low quality evidence for no effect of railway noise on the incidence of prostate cancer.

4.5.3 No studies of other noise sources and the incidence of prostate cancer were identified.

4.6 GRADE assessment –incidence Non-Hodgkin lymphoma

4.6.1 No studies of aircraft noise exposure and incidence of Non-Hodgkin lymphoma were identified.

4.6.2 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise and incidence of Non-Hodgkin lymphoma we considered longitudinal or intervention studies the ideal study design. One longitudinal study available (Sorensen et al., 2015), which we designated as high quality. As only one study was available we were unable to assess inconsistency or indirectness so the evidence was downgraded to low quality (Table 21).

- There is low quality evidence for an effect of road traffic noise on the incidence of Non-Hodgkin lymphoma.

4.6.3 No studies of other noise sources and the incidence of Non-Hodgkin lymphoma were identified.

5 Results for dementia and other neurodegenerative outcomes

5.1.1 The systematic review identified nine studies of associations of environmental noise on dementia and other neurodegenerative outcomes (Andersson et al., 2018; Carey et al., 2018; Carmona, Linares, Recio, Ortiz, & Diaz, 2018; Chen, Kwong, Copes, Hystad, et al., 2017; Chen, Kwong, Copes, Tu, et al., 2017; Culqui, Linares, Ortiz, Carmona, & Diaz, 2017; Diaz et al., 2018; Linares, Culqui, Carmona, Ortiz, & Diaz, 2017; L. Tzivian et al., 2016). Two studies were excluded after data extraction as one did not did not measure noise and the other examined air pollution but not noise exposure (Chen, Kwong, Copes, Hystad, et al., 2017; Chen, Kwong, Copes, Tu, et al., 2017) (see Annex 6: Excluded papers). This left seven studies in the review. Figure 5 summarises the review process.

5.1.2 The studies were from a range of countries, including samples from Germany, Spain, Sweden and the United Kingdom, with a mix of evidence from longitudinal cohort studies and longitudinal time-series studies. The studies consider a range of dementia outcomes including medical diagnoses of Parkinson's Disease, dementia or Alzheimer's Disease, hospitalisations for dementia-related illnesses, as well as cognitive tests of dementia or dementia symptoms or precursors to dementia. Other neurodegenerative outcomes such as multiple sclerosis have been studied in a limited number of studies. The studies examined road traffic noise.

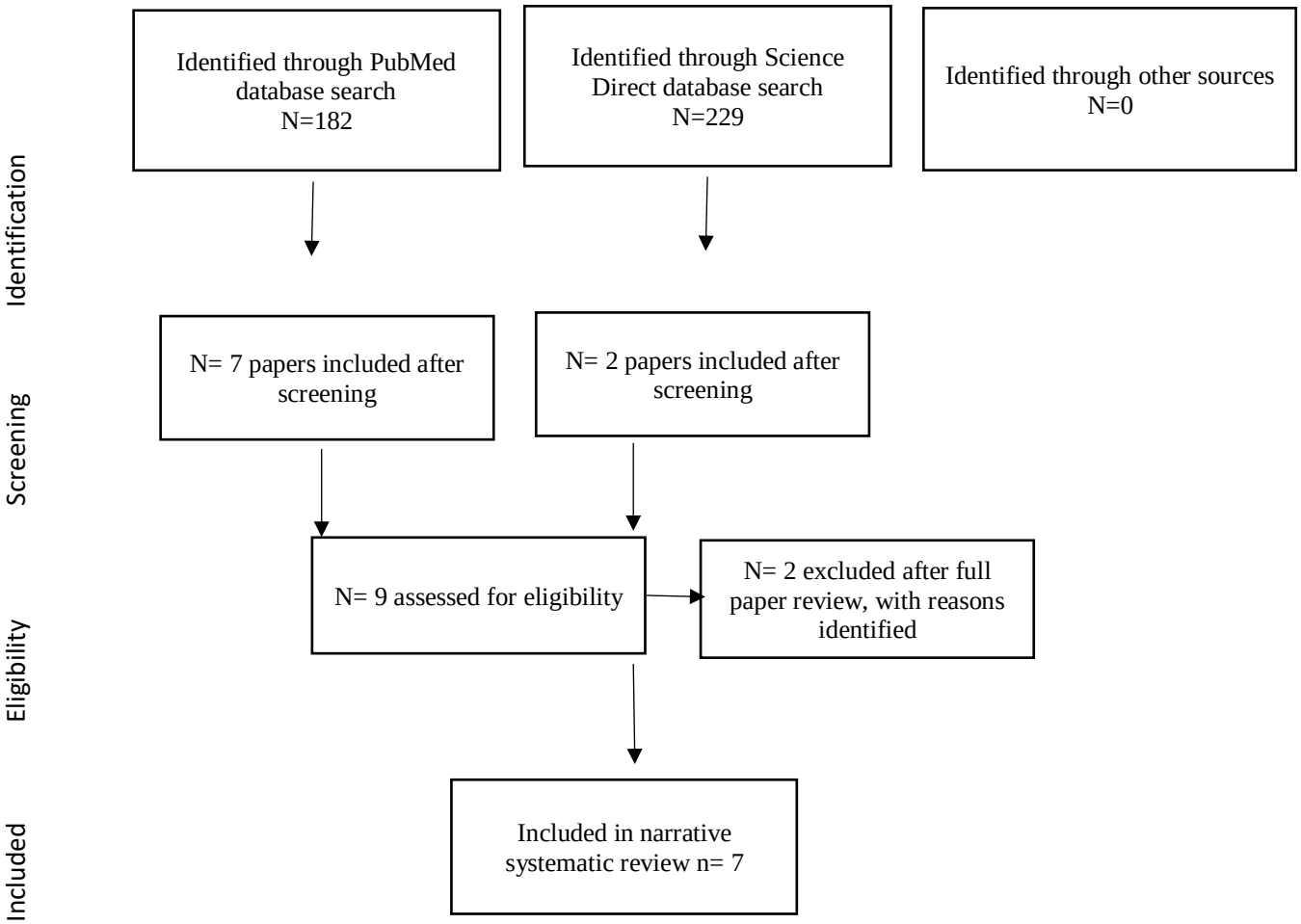
5.1.3 The detailed data extraction for these studies is shown in Table 44 Annex 8: Extraction tables. Only one study was rated as having low bias (Carey et al., 2018), with the other studies rated as having unclear or high bias (See Table 22 Annex 3: Dementia and Other Neurodegenerative Outcomes)

5.1.4 Overall, the evidence for an effect of environmental noise on dementia and neurodegenerative outcomes is mixed. Some studies have found an association between average road noise metrics for the day or night (LAeq 16h/Lnight) and a diagnosis or hospitalisation for dementia (Carey et al., 2018; Linares et al., 2017), hospitalisation for Parkinson's Disease and multiple sclerosis (Carmona et al., 2018; Diaz et al., 2018) or a cognitive assessment of a precursor for dementia (L. Tzivian et al., 2016). However, one of

these studies found that the association between road noise and a diagnosis of dementia became non-significant after adjustment for air pollution (Carey et al., 2018). Two of the seven studies also find no association (Andersson et al., 2018; Culqui et al., 2017). Two Spanish studies (Culqui et al., 2017; Linares et al., 2017) examine the short-term association between road traffic noise exposure and emergency hospitalisations for dementia. The authors speculate that short term exposure to noise may lead to an exacerbation of symptoms of a mental disease such as dementia, which might lead to emergency admission to hospital of persons already suffering from the disease. However, this may be a biased measure of dementia. Evidence suggests that for dementia patients who undergo emergency hospitalisation in the UK, the primary cause is often not their dementia diagnosis per se but attributed to other causes such as syncope (fainting), collapse, bronchopneumonia, urinary tract infection and dehydration (Natalwala, Potluri, Uppal, & Heun, 2008). There are many other factors that are likely to influence emergency hospitalization for dementia patients, making the hypothesis relating to short-term noise exposure seem unlikely. A further two studies from this Spanish research team also assess the short-term associations between road traffic noise exposure and emergency hospitalisation for Parkinson Disease and Multiple Sclerosis (Carmona et al., 2018; Diaz et al., 2018), as well as health care use for Parkinson Disease (Diaz et al., 2018).

5.1.5 The review has identified no evidence relating to the association for dementia with any noise sources other than road traffic noise.

Figure 5 Flow chart showing the review process for the dementia papers



5.2 GRADE assessment for incidence of vascular dementia

5.2.1

Applying the GRADE framework to assess the quality of the evidence across the two studies that assess the incidence of vascular dementia (Andersson et al., 2018; Carey et al., 2018), we considered longitudinal or intervention studies the ideal study design. The studies were longitudinal or retrospective case-control studies, so the evidence was designated as high quality (see Table 22). For road traffic noise, the evidence was downgraded to low quality as there were two reasons to downgrade the evidence: 1) one study had

unclear bias; 2) there was inconsistency in findings across the two studies.

- There is low quality evidence for no effect of road traffic noise on the incidence of vascular dementia.

5.2.2 No studies of other noise sources and the incidence of vascular dementia were identified.

5.3 GRADE assessment for dementia-related emergency admissions

5.3.1 Applying the GRADE framework to assess the quality of the evidence across the two studies that examined dementia-related emergency hospital admissions (Culqui et al., 2017; Linares et al., 2017), we considered longitudinal or intervention studies the ideal study design. The available studies were longitudinal ecological time-series studies, so the evidence was designated as high quality (Table 24). For road traffic noise, the evidence was downgraded to very low quality as there were three reasons to downgrade the evidence: 1) the studies had high or unclear bias; 2) there was inconsistency in findings across the two studies; and 3) the evidence varies across different assessments of dementia and neurodegenerative outcomes (Table 24).

- There is very low quality evidence for an effect of road traffic noise on the dementia-related emergency hospital admissions.

5.3.2 No studies of other noise sources and dementia-related emergency hospital admissions were identified.

5.4 GRADE assessment for cognitive assessment of dementia symptoms

5.4.1 Applying the GRADE framework to assess the quality of the evidence across the one study that reports on a cognitive assessment of dementia symptoms (L. Tzivian et al., 2016) , we considered longitudinal or intervention studies the ideal study design. The study was cross-sectional, so the evidence was designated as low quality (see Table 25). For road traffic noise, the evidence was downgraded

to very low quality as the study had unclear bias and we were unable to assess inconsistency in findings across the studies (Table 25).

- There is very low quality evidence for an effect of road traffic noise on the cognitive assessment of dementia symptoms.

5.4.2 No studies of other noise sources and the cognitive assessment of dementia symptoms were identified.

5.5 GRADE assessment for multiple sclerosis emergency admissions

5.5.1 Applying the GRADE framework to assess the quality of the evidence across the one study that examined multiple sclerosis emergency hospital admissions (Carmona et al., 2018), we considered longitudinal or intervention studies the ideal study design. The available study was a longitudinal ecological time-series studies, so the evidence was designated as high quality (Table 26). For road traffic noise, the evidence was downgraded to very low quality as there were several reasons to downgrade the evidence including unclear bias; and it was not possible to assess inconsistency in findings across studies (Table 26).

- There is very low quality evidence for an effect of road traffic noise on multiple sclerosis emergency hospital admissions.

5.5.2 No studies of other noise sources and multiple sclerosis emergency hospital admissions were identified.

5.6 GRADE assessment for Parkinson's Disease emergency admissions and healthcare

5.6.1 Applying the GRADE framework to assess the quality of the evidence across the one study that examined Parkinson's Disease emergency hospital admissions(Diaz et al., 2018), we considered longitudinal or intervention studies the ideal study design. The available study was a longitudinal ecological time-series studies, so the evidence was designated as high quality (Table 27). For road traffic noise, the evidence was downgraded to very low quality as there were several reasons to downgrade the evidence including

unclear bias; and it was not possible to assess inconsistency in findings across studies (Table 27).

- There is very low quality evidence for an effect of road traffic noise on Parkinson's Disease emergency hospital admissions.

5.6.2 The assessment for the effects of road traffic noise on Parkinson's Disease healthcare use was identical to that stated above for Parkinson's Disease hospital admissions with the following conclusion being drawn:

- There is very low quality evidence for an effect of road traffic noise on Parkinson's Disease healthcare use.

5.6.3 No studies of other noise sources and Parkinson's Disease emergency hospital admissions or healthcare use were identified.

6 Results for birth and reproductive outcomes

6.1.1 The systematic review identified ten studies of associations of environmental noise on birth and reproductive outcomes (A. M. Dzhambov, Markevych, & Lercher, 2019; He et al., 2019; Hjortebjerg, Nybo Andersen, Ketzel, Raaschou-Nielsen, & Sorensen, 2018; Min & Min, 2017; Nassan et al., 2018; Pedersen et al., 2017; Poulsen et al., 2018; Robinson et al., 2018; Smith et al., 2017; Wallas et al., 2019). Three studies were excluded after data extraction (see Annex 6: Excluded papers). One study was excluded as it reported exposure during pregnancy but no relevant health outcomes (Robinson et al., 2018). One study was about post-partum depression rather than a birth outcome for the infant, per se, so this paper was moved to the review for mental health, wellbeing and quality of life (He et al., 2019). One study measured distance to road and not noise exposure, per se (Nassan et al., 2018). This left seven studies in the review. Figure 6 summarises the review process.

6.1.2 The studies were of samples from Austria/Italy, Canada, Denmark, Korea, Sweden and the United Kingdom, with evidence from longitudinal and retrospective cohort studies. Most studies examined road traffic noise, with one study examining wind-turbine noise (Poulsen et al., 2018). The studies considered a range of birth outcomes including pre-term birth, low birth weight, small for gestational age, as well as Body Mass Index (BMI). One study examined the association between road noise and medically assessed male infertility (Min & Min, 2017) and another examined the association between road traffic noise and febrile seizures[15] in childhood (Hjortebjerg et al., 2018). One study examined congenital abnormalities at birth (Pedersen et al., 2017).

6.1.3 The detailed data extraction for these studies is shown in Table 45 Annex 8: Extraction tables. The studies were individually all rated as having low bias (see Table 28 Annex 4: Birth and Reproductive Outcomes).

6.1.4 Overall, the evidence does not support an effect of environmental noise on birth outcomes. Most studies do not demonstrate effects of road traffic exposure with a range of birth outcomes (Pedersen et al.,

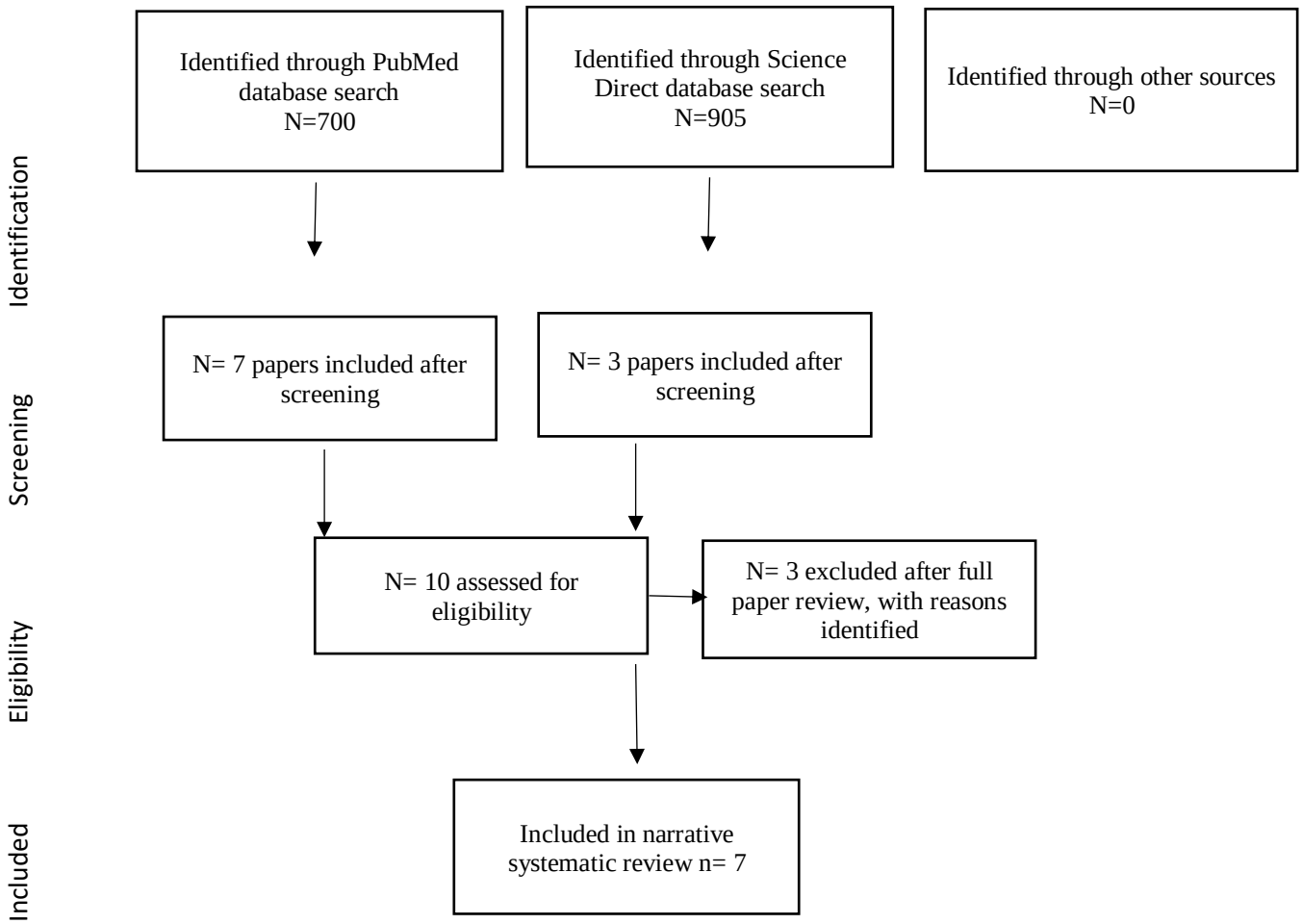
[15] Febrile seizures are full-body convulsions caused by a high fever in childhood.

2017; Smith et al., 2017; Wallas et al., 2019). One study found an association of road noise on BMI in later but not early childhood (Wallas et al., 2019). This study also found that road traffic noise was associated with a decreased risk of pre-term birth (Wallas et al., 2019). Another study found only a trend for decreasing birth weight with road noise exposure, but this was attenuated with adjustment for air pollution and concluded that "The results suggest little evidence for an independent exposure-response effect of traffic related noise on birth weight outcomes." (Smith et al., 2017). One study found an effect of road/rail noise on low birth weight but this association was only demonstrated in one of the samples examined: in the other sample the association was only significant when further adjusted for air pollution: this study also unexpectedly found that as Lden increased the odds for small for gestational age decreased (A. M. Dzhambov et al., 2019). Another study found no association between road traffic noise in the first trimester and congenital birth outcomes (Pedersen et al., 2017). One study found an association between railway noise exposure and road traffic noise exposure and febrile seizures in childhood. The one study of male infertility, also found an association with road traffic noise exposure (Min & Min, 2017).

6.1.5 The study of wind turbine noise found no evidence for associations between night-time wind turbine noise during pregnancy and pre-term birth, low birth weight or being small for gestational age using data covering over 135,000 pregnant women in Denmark between 1982 and 2013 (Poulsen et al., 2018).

6.1.6 The review found no evidence relating to the associations of birth or fertility outcomes with aircraft noise or other environmental noise sources.

Figure 6 Flow chart showing the review process for the birth outcome papers



6.2 GRADE assessment for birth weight

6.2.1

Applying the GRADE framework to assess the quality of evidence across the two studies of road traffic noise and low birthweight we considered longitudinal or intervention studies the ideal study design. Two longitudinal studies were available (Smith et al., 2017; Wallas et al., 2019), which were designated as high quality. No further reasons to downgrade the evidence were identified (Table 29).

- There is high quality evidence for no effect of road traffic noise on birthweight.

6.2.2

Applying the GRADE framework to assess the quality of evidence across the study wind turbine noise and low birthweight we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Poulsen et al., 2018),

which was designated as high quality. As it was not possible to assess inconsistency across the evidence, this was downgraded to moderate quality evidence.

- There is moderate quality evidence for no effect of wind turbine noise on birthweight.

6.2.3 Applying the GRADE framework to assess the quality of evidence across the study of railway noise and low birthweight we considered longitudinal or intervention studies the ideal study design. One cross-sectional study was available (A. M. Dzhambov et al., 2019), which was designated as low quality. As it was not possible to assess inconsistency across the evidence and that the evidence from this study was inconsistent across the samples, this was downgraded to very low quality evidence.

- There is very low quality evidence for no effect of railway noise on birthweight.

6.2.4 No studies of other noise sources and low birthweight were identified.

6.3 GRADE assessment for pre-term birth

6.3.1 Applying the GRADE framework to assess the quality of evidence of the evidence for road traffic noise and pre-term birth we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Wallas et al., 2019), which was designated as high quality. As it was not possible to assess inconsistency across the evidence, this was downgraded to moderate quality evidence (Table 30).

- There is moderate quality evidence for no effect of road traffic noise on pre-term birth.

6.3.2 Applying the GRADE framework to assess the quality of evidence across the study wind turbine noise and pre-term birth we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Poulsen et al., 2018), which was designated as high quality. As it was not possible to assess

inconsistency across the evidence, this was downgraded to moderate quality evidence (Table 30).

- There is moderate quality evidence for no effect of wind turbine noise on pre-term birth.

6.3.3 No studies of other noise sources and pre-term birth were identified.

6.4 GRADE assessment for small for gestational age

6.4.1 Applying the GRADE framework to assess the quality of evidence across the two studies of road traffic noise and being small for gestational age we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Smith et al., 2017), which was designated as high quality. This was downgraded to moderate quality evidence due to inconsistency between the study evidence (Table 31).

- There is moderate quality evidence for no effect of road traffic noise on being small for gestational age.

6.4.2 Applying the GRADE framework to assess the quality of evidence across the study wind turbine noise and being small for gestational age we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Poulsen et al., 2018), which was designated as high quality. As it was not possible to assess inconsistency across the evidence, this was downgraded to moderate quality evidence (Table 31).

- There is moderate quality evidence for no effect of wind turbine noise on being small for gestational age.

6.4.3 Applying the GRADE framework to assess the quality of evidence across the study of railway noise and being small for gestational age we considered longitudinal or intervention studies the ideal study design. One cross-sectional study was available (A. M. Dzhambov et al., 2019), which was designated as low quality. As it was not possible to assess inconsistency across the evidence, this was downgraded to very low quality evidence (Table 31).

- There is very low quality evidence for no effect of railway noise on being small for gestational age.

6.5 GRADE assessment for congenital abnormalities

6.5.1 Applying the GRADE framework to assess the quality of evidence across the two studies of road traffic noise and congenital abnormalities we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Pedersen et al., 2017), which we designated as high quality. This was downgraded to low quality as we were unable to assess inconsistency or indirectness (Table 32).

- There is low quality evidence for no effect of road traffic noise on congenital abnormalities.

6.5.2 No studies of other noise sources and congenital abnormalities were identified.

6.6 GRADE assessment for febrile seizures

6.6.1 Applying the GRADE framework to assess the quality of evidence for road traffic noise and febrile seizures we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Hjortebjerg et al., 2018), which we designated as high quality. This was downgraded to low quality as we were unable to assess inconsistency or indirectness (Table 33).

- There is low quality evidence for an effect of road traffic noise on febrile seizures.

6.6.2 No studies of other noise sources and febrile seizures were identified.

6.7 GRADE assessment for male fertility

6.7.1 Applying the GRADE framework to assess the quality of evidence for road traffic noise and febrile seizures we considered longitudinal or intervention studies the ideal study design. One longitudinal study was available (Min & Min, 2017), which we designated as high

quality. This was downgraded to low quality as we were unable to assess inconsistency or indirectness (Table 34).

- There is low quality evidence for an effect of road traffic noise on male fertility.

6.7.2 No studies of other noise sources and male fertility were identified.

6.8 Comparison of review findings with the WHO review

6.8.1 Given the greater breadth of the WHO systematic review for birth outcomes, it is prudent to consider whether the strength of the evidence identified within the WHO review is informative over and above the conclusions of the current review, which only covers a limited time-frame. The key question is whether the studies identified in the current review would alter or strengthen the conclusions of the WHO review.

6.8.2 The conclusions regarding the strength of the evidence for the WHO (Nieuwenhuijsen et al., 2017) review is provided in Figure 7.

Figure 7 Summary of the findings of Nieuwenhuijsen et al., 2017 systematic review of environmental noise and adverse birth outcomes for the WHO Environmental Noise Guidelines.

Nieuwenhuijsen et al., 2017 – Adverse birth outcomes

Method: The WHO review identified 14 papers using

- a systematic review search covering June 2014-December 2016; and
- the reference lists of three previously published systematic reviews (papers identified back to 1973).

WHO conclusions regarding the strength of the evidence:

- very low quality for associations between aircraft noise and preterm birth, low birth weight and congenital anomalies
- low quality evidence for an association between road traffic noise and low birth weight, preterm birth and small for gestational age.

Research gaps & needs:

- Concluded that further high-quality studies were required to establish the associations and that future studies needed to apply robust exposure assessment methods, to disentangle associations for different sources of noise as well as daytime and night-time noise, as well to better control for confounding factors such as socioeconomic status, lifestyle factors and other environmental factors, including air pollution.

6.8.3 The current review identified no papers of aircraft noise, therefore, we consider the conclusions of the WHO review (Nieuwenhuijsen et al., 2017) regarding aircraft noise and birth outcomes to stand.

6.8.4 For road noise and birthweight, the findings of the current review differ from those of the WHO review. The WHO review concluded based on the findings of eight studies that there was 'low quality evidence for an association of road traffic noise on low birth weight', whereas the current review concludes that there is high quality evidence for no effect of road traffic noise on birthweight, based on the findings of two longitudinal studies. In examining the WHO review findings, despite the conclusion the evidence was quite mixed with only some studies showing an association. The GRADE used in both reviews is precautionary, in that, if some but not all evidence

shows an effect then the conclusion will indicate that there is an effect.

6.8.5 Overall, the findings of the current review add to the equivocality of the evidence regarding birth weight. It may now be appropriate to meta-analyse the data for road traffic noise and birth weight to assess whether the effect can be demonstrated statistically. For the UK context, the evidence from the large-scale study by Smith et al. (2017) is compelling and should perhaps inform the conclusion that at present for the UK it is appropriate to consider that there is no effect of road traffic noise on birth weight.

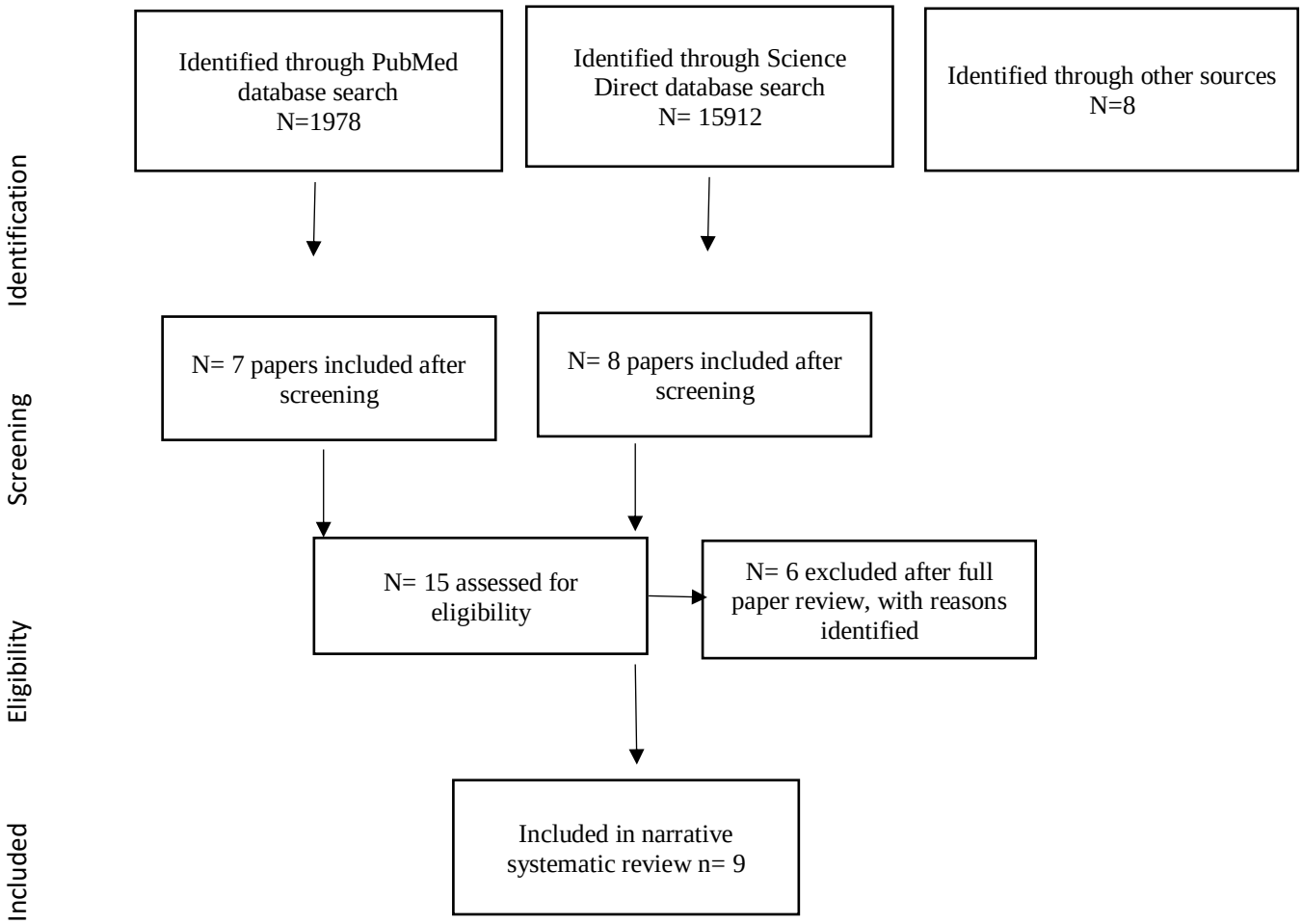
7 Results for cognition

7.1.1 The systematic review identified nine studies of associations of environmental noise on cognition (Braat-Eggen, van Heijst, Hornikx, & Kohlrausch, 2017; Connolly et al., 2019; Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016; Onchang & Hawker, 2018; Papanikolaou, Skenteris, & Piperakis, 2015; Silva, Oliveria, & Silva, 2016; L. Tzivian et al., 2016; Tzivian et al., 2017; Van Aart et al., 2018). Studies examined child and adult samples. A further three studies from the NORAH study, known to the report authors were added: one that had not been identified by the systematic searches (Klatte et al., 2016), as well as three conference papers (Foraster et al., 2019; Spilski, Bergstrom, et al., 2017; Spilski, Mayerl, Bergstrom, & Mohler, 2017). Two other studies known to the authors were also added (Eagan, Nicholas, McIntosh, Clark, & Evans, 2017; Seabi, Cockcroft, Goldschagg, & Greyling, 2015), along with another recent conference paper (Foraster et al., 2019). Six studies were excluded after data extraction (see Annex 6: Excluded papers). Two studies which reported experimental studies (Braat-Eggen et al., 2017; Connolly et al., 2019); one that reported mental health not cognition and had already been identified in the search for mental health (Van Aart et al., 2018); one which did not report on noise exposure per se (Onchang & Hawker, 2018), and another study which reported a ADHD outcome, which was moved to the mental health review (Forns, Dadvand, Foraster, Alvarez-Pedrerol, Rivas, López-Vicente, et al., 2016). One study reported on attitudes to noise within the school and did not report a cognitive outcome (Silva et al., 2016). This left nine studies in the final review. Figure 8 summarises the review process.

7.1.2 The studies were from Germany, Greece, Spain, South Africa and the United States, with a mix of evidence from longitudinal cohort studies and cross-sectional studies. The studies consider a range of cognitive outcomes including cognitive testing of reading and mathematics for children, as well as cognitive testing of adults. One study reported on an observational study of student distraction by aircraft noise during class: this is a potentially weaker measure of cognition but is included in the review given the limited studies available. One study examined the effect of road traffic noise at school on developmental trajectories for working memory and

attention. The available studies were focused on road traffic noise and aircraft noise exposure.

Figure 8 Flow chart showing the review process for the cognition papers



7.1.3 The detailed data extraction for these studies is shown in Table 46 Annex 8: Extraction tables. The studies were individually rated as having low to high bias (see Table 35 Annex 5: Cognition):

7.1.4 Overall, the evidence for an effect of environmental noise on cognition for children and adults is mixed. The two studies of adult samples (L. Tzivian et al., 2016; Tzivian et al., 2017) both found an association between long-term exposure to road traffic noise and cognitive impairment; however, for one study the association was only observed for those who also had co-occurring high air pollution exposure (Tzivian et al., 2017).

7.1.5 The cross-sectional NORAH study of 1242 primary school children (mean age 8 years 4 months), from 29 primary schools around Frankfurt airport in Germany, found that a 10dB (LAeq 08.00am-14.00pm) increase in aircraft noise exposure at school was associated with a decrement of one-tenth of a standard deviation on a standardized German reading test, which corresponded to a one-month delay in terms of reading age (Klatte et al., 2016; Spilski, Bergstrom, et al., 2017). The NORAH study found relationships between aircraft noise at school with the sub-scales of the reading test – word comprehension and text comprehension. The overall NORAH finding of an effect was similar to that previously observed in the RANCH study (Clark et al., 2006). The NORAH study also found that maximum sound levels (LAmax 0800-14.00), difference between LAmax and LAeq (emergence) and number above thresholds (0800-14.00) was associated with distraction during in lessons, which in turn was a significant predictor of children's reading performance: however, this was only examined in a sub-sample of children who had a migration background (Spilski, Mayerl, et al., 2017). The number above metrics served as a second unique predictor over and above daytime LAeq and the study concluded that both the average noise intensity (e.g. LAeq) and the number of flight events above a certain threshold (NA metric) should be considered. An observational study of children around Los Angeles airport found associations between short-term exposure to aircraft noise events and teacher voice masking and voice raising behaviour but no effect on student distraction (Eagan et al., 2017). A longitudinal study of the effects of a reduction in aircraft noise associated with the relocation of an airport, found no significant effect on reading comprehension of the reduction in aircraft noise

exposure (Seabi et al., 2015), but this study may be biased by loss-to-follow up in the sample.

7.1.6 A study from Greece found evidence for associations of road traffic noise on children's reading and mathematics but the study findings may be biased as they do not adjust for other covariates or confounding variables (Papanikolaou et al., 2015).

7.1.7 A study from Spain found that road traffic noise at school was associated with the developmental trajectories of children's working memory and attention skills (Foraster et al., 2019).

7.2 GRADE assessment for reading comprehension

7.2.1 Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise on reading comprehension, we considered longitudinal or intervention studies the ideal study design. For aircraft noise, one of the four studies available was longitudinal, so we designated the evidence as high quality. The evidence was downgraded to very low quality for three reasons: 1) a high risk of bias for one study, 2) the evidence varies across the different studies available, and 3) some evidence only finds effects for sub-groups of the population (Table 36).

- There is very low quality evidence for an effect of aircraft noise on reading comprehension.

7.2.2 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on reading comprehension, we considered longitudinal or intervention studies the ideal study design. For road traffic noise, the one study available was cross-sectional, so we designated the evidence as low quality. The evidence was downgraded to very low quality for three reasons: 1) a high risk of bias for the study, 2) being unable to assess inconsistency as only one study was available so no comparison could be made across study findings and 3) indirectness (Table 36).

- There is very low quality evidence for an effect of road traffic noise on reading comprehension.

7.2.3 No studies of other noise sources and reading comprehension were identified.

7.3 GRADE assessment for mathematics

7.3.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise on mathematics, we considered longitudinal or intervention studies the ideal study design. For road traffic noise, the one study available was cross-sectional, so we designated the evidence as low quality. The evidence was downgraded to very low quality for three reasons: 1) a high risk of bias for the study, 2) being unable to assess inconsistency and 3) indirectness (Table 37).

- There is very low quality evidence for an effect of road traffic noise on mathematics.

7.3.2 No studies of other noise sources and mathematics were identified.

7.4 GRADE assessment for assessments of student distraction

7.4.1 Applying the GRADE framework to assess the quality of evidence across the available studies of aircraft noise effects on student distraction, we considered longitudinal or intervention studies the ideal study design. One cross-sectional study was available, so we designated the evidence as low quality. The evidence was downgraded to very low quality due to the high risk of bias and being unable to assess inconsistency (Table 38).

- There is very low quality evidence for an effect of aircraft noise on student distraction.

7.4.2 No studies of other noise sources and assessments of student distraction were identified.

7.5 GRADE assessment for assessments of adult cognition

7.5.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise assessments and

adult cognition, we considered longitudinal or intervention studies the ideal study design. For road traffic noise, two cross-sectional studies were available, so we designated the evidence as low quality. The evidence was downgraded to very low quality due to the inconsistent evidence (Table 39).

- There is very low quality evidence for an effect of road traffic noise on assessments of adult cognition.

7.5.2 No studies of other noise sources and assessments of adult cognition were identified.

7.6 GRADE assessment for assessments of working memory and attention in children

7.6.1 Applying the GRADE framework to assess the quality of evidence across the available studies of road traffic noise assessments and children's working memory, we considered longitudinal or intervention studies the ideal study design. For road traffic noise, one longitudinal study was available, so we designated the evidence as high quality. The evidence was downgraded low quality due to being unable to assess inconsistency across studies and for unclear bias regarding the information reported for sampling for this study (Table 40).

- There is low quality evidence for an effect of road traffic noise on working memory in children.

7.6.2 The GRADE assessment for the quality of the evidence across the available studies of road traffic noise assessments and children's attentional skills is the same as that described above for working memory (Table 40), with the following conclusion:

- There is low quality evidence for an effect of road traffic noise on attention in children.

7.6.3 No studies of other noise sources and assessments of children's working memory and attention were identified.

7.7 Comparison of the review findings with the WHO review

7.7.1 Given the greater breadth of the WHO systematic review for cognition, it is prudent to consider whether the strength of the evidence identified within the WHO review is informative over and above the conclusions of the current review, which only covers a limited time-frame. The key question is whether the studies identified in the current review would alter or strengthen the conclusions of the WHO review.

7.7.2 The conclusions regarding the strength of the evidence for the WHO (Clark & Paunović, 2018b) review are provided in Figure 9.

7.7.3 The conclusions of the WHO review (Clark & Paunović, 2018b) differ to those of the current review. For reading comprehension, the WHO review concluded that there was "moderate quality evidence for an effect of aircraft noise on children's reading and oral comprehension" and "low quality evidence for no substantial effect of road traffic noise on children's reading and oral comprehension". The current review finds low quality evidence for an effect of aircraft noise and road traffic noise on children's reading comprehension. However, this reflects the smaller number of studies in the current review, despite the inclusion of methodologically robust studies such as NORAH (Klatte et al., 2016). This is because methodologically weaker studies included within the body of evidence impact on the GRADE process and result in downgrading. For reading comprehension the WHO review included 14 studies of aircraft noise and two studies of road traffic noise, whereas the current review included four studies of aircraft noise and one study of road traffic noise. The additional aircraft noise studies identified since the WHO 2017 review would not conflict with conclusions of the WHO review evidence base, which was assessed as moderate based on a low risk of bias but some inconsistency of findings across the studies. The WHO review conclusions should be considered to stand in light of the current review's conclusions.

7.7.4 For road traffic noise the WHO conclusion was based on two studies showing no effect on reading comprehension (both of which reported on the RANCH study) and the current review now identifies one additional paper that shows an effect but is not methodologically robust. Taking the precautionary approach, we could recommend the

finding of the current review that there is 'very low quality evidence for an effect of road traffic noise on reading comprehension'. However, this conclusion has to be tempered by the high risk of bias for the one study on which the conclusion was based which did not clearly report how children were recruited and did not adjust the finding for confounding factors, versus the large-scale methodologically robust RANCH study which has clear relevance of the UK context. At this stage, until further evidence is available, it would be prudent to rely on the WHO review's conclusion.

7.7.5 The WHO review concluded that there was low quality evidence for no effect of road traffic noise on executive function/working memory based on five cross-sectional studies. The current review concludes that there is low quality evidence for an effect of road traffic noise on working memory in children based on one longitudinal study. Comparing the conclusions therefore involves weighing up a few cross-sectional studies versus one longitudinal study: as a precautionary approach the conclusion of the current review is put forward as an update to the WHO conclusion.

7.7.6 The WHO review concluded that there was very low quality evidence for no effect of road traffic noise on attention based on five cross-sectional studies. The current review concludes that there is low quality evidence for an effect of road traffic noise on attention in children based on one longitudinal study. Comparing the conclusions therefore involves weighing up a few cross-sectional studies versus one longitudinal study: as a precautionary approach the conclusion of the current review is put forward as an update to the WHO conclusion.

Figure 9 Summary of the findings of Clark & Paunović, 2018b systematic review of environmental noise and cognition for the WHO Environmental Noise Guidelines.

Clark & Paunović, 2018b – Cognition

Method: The WHO review identified 34 papers using

- a systematic review search covering all papers with no start date up to June 2015.

WHO conclusions regarding the strength of the evidence:

- There was moderate quality evidence for an effect of aircraft noise on children's reading and oral comprehension and low quality evidence for no substantial effect of road traffic noise on children's reading and oral comprehension.
- There was moderate quality evidence for an association of aircraft noise and railway noise, and very low quality evidence for an association of road traffic noise exposure with poorer performance on standardized assessment tests.
- There was moderate quality evidence for aircraft noise being associated with children having poorer long-term memory. Evidence for an effect of road traffic noise and for railway noise was rated as very low quality.
- There was a lack of studies examining effects on short-term memory.
- There was low quality evidence for no substantial effect of aircraft noise on children's attention; the evidence for no substantial effect of road traffic noise and railway noise was rated as very low quality.
- There was very low quality evidence for aircraft noise and low quality evidence for road traffic noise for no substantial effect on executive function (working memory), with studies consistently suggesting no association for aircraft noise or road traffic noise.

Research gaps & needs:

- Studies of other noise sources, such as railway noise, on children's reading and oral comprehension were lacking. Further studies of road traffic noise exposure would also prove useful.
- Lack of evidence from longitudinal and intervention studies.

8 Discussion & Recommendations for IGCB(N)

8.1.1 This section discusses the evidence review and considers the implications of the findings for the IGCB(N). The following factors have informed the recommendations:

- Whether the review (or the WHO reviews, see earlier discussions) consider there is a harmful effect or no effect of the environmental noise exposure on the outcome. Where no effect is identified, no recommendation is provided, as there is no need to quantify the effect of the exposure on the health outcome.

- Given the breadth of outcomes available for most of the health and cognitive outcomes examined in the review, recommendations are made on the basis of the strongest epidemiological outcomes, where possible, so for example, the incidence of dementia or depression, rather than assessments of symptoms.

- As meta-analyses have not been undertaken, recommendations regarding the evidence follow previous IGCB(N) approaches, in terms of recommending ERFs for a particular noise source and outcome. Previous IGCB(N) recommendations have also applied ERFs from one noise source, to estimate effects for a different noise source, where noise source specific ERFs are not yet available. This approach has also been taken here.

8.1.2 Noise sources: The scope of this review included a wide-range of environmental noise sources, yet the available evidence predominantly relates to road traffic noise, aircraft noise and railway noise. There are very few studies of the other environmental noise sources including wind turbine noise, building services noise, ventilation noise, neighbour noise, industrial noise, leisure noise or combined noise. The health effects of these noise sources remain unquantified.

8.1.3 Mental health: A large body of evidence was identified relating to environmental noise effects on mental health, but this is an area that is still beset by some poor quality studies for many outcomes. In terms of mental health, wellbeing and quality of life evidence from UK studies is mixed and limited to self-reported health, quality of life and wellbeing measures. The national Survey of Noise Attitudes 2014 failed to find associations between aircraft noise (LAeq 16h)

and self-reported health or the Warwick Edinburgh Mental Wellbeing Scale, although it did find associations for these outcomes with noise annoyance (Civil Aviation Authority, 2017). A UK study using Census data for people living around 17 airports and a measure of wellbeing, found that day-time aircraft noise was associated with wellbeing (Lawton & Fujiwara, 2016): no association was found between night-time aircraft noise exposure and wellbeing. Another study from the United Kingdom using Census data from around Belfast Airport failed to find an association between aircraft noise and self-reported mental health assessed as "an emotional, psychological or mental health condition (such as depression or schizophrenia)" (Wright et al., 2018). There is a need for longitudinal surveys in the UK that assess symptoms and interview measures of depression and anxiety, as well as self-reported depression, anxiety and psychological symptoms. However, if you consider the past reviews (Clark, Myron, Stansfeld, & Candy, 2007; Clark & Paunović, 2018a) alongside the current review, it can be concluded that there is enough evidence for ERFs between noise (road, railway, aircraft) and adult and childhood mental health. Following previous IGCB(N) approaches it would be possible, for example, to use the NORAH study for adult mental health (Seidler et al., 2017) that assessed the incidence of depression and anxiety. However, as the aircraft ERF is not reliable at higher exposures it may be appropriate to use the road ERF from this study for all noise sources until further ERFs become available. For children, several methodologically robust studies are available that could also be used such as those identified in the WHO review for road traffic noise and railway noise such as Dreger et al. (2015) which examines incident mental health symptoms. This should not, however, be applied for aircraft noise, as neither the WHO review or this review found evidence for an effect for aircraft noise.

8.1.4 Wellbeing: Whilst wellbeing as a concept has risen in popularity in recent years, the review identified relatively few studies of environmental noise and wellbeing. The review concluded that there was very low quality evidence for an effect of aircraft noise on wellbeing. As for mental health, it would be possible to use a study from this evidence base, for example Lawton and Fujiwara (2016), to estimate noise effects on wellbeing.

8.1.5 Quality of life: No recommendation is made for quality of life, as both this review and the WHO review concluded that there was very

low quality evidence for no effect of aircraft noise on self-reported health or quality of life. The WHO review came to the same conclusion for road traffic noise but did find very low quality evidence for a harmful effect for railway noise. This is a research area that should be watched to see if methodologically robust evidence for a harmful effect becomes available in the next few years.

8.1.6 Cancer: This review is one of the first to consider the emerging body of evidence for environmental noise effects on cancer. Overall, given the number of studies available, the evidence is quite convincing for effects of aircraft noise, road traffic noise and railway noise on some cancer outcomes. However, no evidence is yet available for the UK. For estimating effects at the population level, it would be useful to have evidence or an ERF for a relevant population-level cancer outcome, such as all-cause mortality from cancer. At present the data only supports an effect for some types of cancer and at present, even different types of the same cancer show different associations. At this point, given that most of the evidence currently comes from one Danish birth cohort it is worth keeping a watching brief on this area, as further evidence becomes available which consider wider population measures of cancer.

8.1.7 Dementia and other neurological conditions: The review has concluded that there is low quality evidence for no effect of road traffic noise on the incidence of vascular dementia. Evidence is available from a large-scale methodologically robust UK study which found that the association between road noise and an incidence diagnosis of dementia became non-significant after adjustment for air pollution (Carey et al., 2018). Therefore, no study is recommended to the IGCB(N) for this health outcome. There is very limited evidence relating to other neurological conditions and no studies of incidence, to date.

8.1.8 Birth and other reproductive outcomes: Overall, evidence for effects on birth and other reproductive outcomes remains equivocal, with most studies showing no association. It may now be appropriate to meta-analyse the data for road traffic noise and birth weight to assess whether the effect can be demonstrated statistically, however, for the UK context, the evidence from the large-scale study by Smith et al. (2017) is compelling and informs the conclusion that at present for the UK it is appropriate to conclude that there is no effect of road

traffic noise on birth weight and to apply this finding to other noise sources.

8.1.9 Cognition: Evidence from the methodologically robust NORAH study (Klatte et al., 2016) confirms the findings of the UK-relevant RANCH study in terms of effects on children's reading comprehension (Clark et al., 2006). The evidence is certainly strong enough to support applying the aircraft noise ERFs from RANCH or NORAH to estimate effects of environmental noise on children's reading comprehension. However, the RANCH study did not find an effect of road traffic noise on reading comprehension, which suggests that the aircraft noise relationship should not be applied for road traffic noise. Studies of adulthood cognition are starting to emerge, particularly in relation to the development of dementia in later-life. Given the overlap in the evidence to date, this should be considered in relation to dementia as an outcome and not cognition.

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10 Annex

10.1 Annex 1: Mental health, wellbeing and quality of life

Table 6 Mental health, wellbeing and quality of life: Risk of Bias

Reference	Bias due Exposure Assessment	Bias due to Confounding	Bias due to Selection of Participants	Bias due to Health Outcome Assessment	Bias due to Not Blinded Outcome Assessment	Total Risk of Bias
Weyde, Envt Health, 2017	Low	Low	High	Unclear	Low	High
Feder et al., Environ Res, 2015	Low	Low	Low	Low	Low	Low
Seidler et al., Environ Res, 2017	Unclear	Low	Low	Low	Low	Unclear
Welch et al., Noise Health, 2018	Low	Unclear	Low	Low	Low	Unclear
Klatte et al., Environ & Behavior, 2016	Low	Low	Low	Low	Low	Low
Dzhambov et al., Environ Res, 2018a	Low	Low	Unclear	Low	Low	Unclear
Generaal et al., Psychol Med, 2019	Low	Low	High	Low	Low	Unclear
Dzhambov et al., Environ Res, 2018b	Low	Low	Unclear	Low	Low	Unclear
Dzhambov et al., Environ Int., 2017	Low	Low	Unclear	Low	Low	Unclear
Zock et al., Environ Int., 2018	Low	Low	Low	Low	Low	Low
Lim et al., Noise Health, 2018	Low	Low	High	Low	Low	Unclear
Forns et al., Enviro Health Perspectives, 2016	Low	Low	Low	Low	Low	Low
He et al., Environ Res., 2019	Low	Low	Unclear	Low	Low	Unclear
Civil Aviation Authority, 2017	Low	High	Low	Low	Low	Unclear
Van Aart et al., Environ Int., 2018	Low	Low	High	Low	Low	Unclear
Klompmaker et al., Environ Int., 2019	Low	Low	Unclear	Low	Low	Unclear
Okokon et al., Environ Int., 2018	Low	Low	Unclear	Low	Low	Unclear

Oiamo et al., Soc Sci Med., 2015	Low	High	Unclear	Low	Low	Unclear
Leijssen et al., IJERPH, 2019	Low	Low	Low	Low	Low	Low
Zijlema et al., Int. J Hygiene E Health., 2015	Low	Low	Unclear	Low	Low	Unclear
Wallas et al., Int. J Hygiene E Health., 2018	Low	Unclear	High	Low	Low	Unclear
Lawton et al., Transport Res Part D., 2016	Low	Low	Low	Low	Low	Low
Wright et al., Environ Health., 2018	Low	Low	Low	Low	Low	Low
Zijlema et al., Internoise., 2019	Low	Low	Unclear	Low	Low	Unclear

Table 7 GRADE for the quality of evidence of environmental noise being associated with self-reported quality of life or health

	AIRCRAFT NOISE (4 STUDIES (1 CHILD/3 ADULT))			WIND TURBINE NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional studies only	Low quality	Intervention/ Longitudinal	One cross-sectional study	Low quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	Downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality			Very low quality

Table 8 GRADE for the quality of evidence of environmental noise being associated with self-reported depression, anxiety and psychological symptoms

	ROAD NOISE (7 STUDIES)			RAILWAY NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional studies only	Low quality	Intervention/ Longitudinal	Cross-sectional studies only	Low quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality			Very low quality

Table 9 GRADE for the quality of evidence of environmental noise being associated with interview measures of depressive and anxiety disorders

	AIRCRAFT NOISE (2 STUDIES)			ROAD TRAFFIC NOISE (4 STUDIES)			RAILWAY NOISE (3 STUDIES)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study longitudinal	High quality	Intervention/ Longitudinal	Two longitudinal studies	High quality	Intervention/ Longitudinal	One study longitudinal	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade	Study quality & bias	Unclear risk of bias	Downgrade	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade

5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality			Low quality			Low quality

Table 10 GRADE for the quality of evidence of environmental noise being associated with wellbeing

	AIRCRAFT NOISE (3 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional evidence only	Low quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

Table 11 GRADE for the quality of evidence of environmental noise being associated with emotional and conduct symptoms in children

	ROAD NOISE (3 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Longitudinal evidence available	High quality
1. Study Design	Study quality & bias	Unclear or high risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

Table 12 GRADE for the quality of evidence of environmental noise being associated with hyperactivity

	ROAD NOISE (3 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Longitudinal evidence available	High quality
1. Study Design	Study quality & bias	Unclear or high risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

Table 13 GRADE for the quality of evidence of environmental noise being associated with cortisol in children

	ROAD NOISE (1 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional evidence available	Low quality
1. Study Design	Study quality & bias	Unclear or high risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

Table 14 GRADE for the quality of evidence of environmental noise being associated with medication intake for the treatment of anxiety and depression

	ROAD TRAFFIC NOISE (2 STUDIES)			RAILWAY NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional evidence	Low quality	Intervention/ Longitudinal	Cross-sectional evidence	Low quality
1. Study Design	Study quality & bias	Low risk of bias	Downgrade	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	Indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality			Very low quality

Table 15 GRADE for the quality of evidence of environmental noise being associated with ADHD in children

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One cross-sectional study	Low quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

10.2 Annex 2: Cancer

Table 16 Cancer: Risk of Bias

Reference	Bias due Exposure Assessment	Bias due to Confounding	Bias due to Selection of Participants	Bias due to Health Outcome Assessment	Bias due to Not Blinded Outcome Assessment	Total Risk of Bias
Andersen et al., Lynge Breast Cancer Res., 2018	Low	Low	Low	Low	Low	Low
Hegewald et al., Scandinavian J Work Envt Health, 2017	Low	Low	Low	Low	Low	Low
Roswall et al., Environ Research, 2016	Low	Low	Low	Low	Low	Low
Roswall, et al., Cancer, Causes & Control, 2017	Low	Low	Low	Low	Low	Low
Roswall et al., PloS One, 2015	Low	Low	Low	Low	Low	Low
Roswall et al., PloS One, 2017	Low	Low	Low	Low	Low	Low
Sorensen et al., I J of Cancer, 2014	Low	Low	Low	Low	Low	Low
Sorensen et al., Environmental Research, 2015	Low	Low	Low	Low	Low	Low

Table 17 GRADE for the quality of the evidence for effects of environmental noise on the incidence of breast cancer

	AIRCRAFT NOISE (1 STUDY)			ROAD TRAFFIC NOISE (3 STUDIES)			RAILWAY NOISE (2 STUDIES)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study longitudinal	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade	Direct comparison; same PECCO	Indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality			Low quality			Low quality

Table 18 GRADE for the quality of the evidence for effects of environmental noise on cancer mortality

	ROAD TRAFFIC NOISE (2 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Consistent evidence; I2 not assessed	No downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			High quality

Table 19 GRADE for the quality of the evidence for effects of environmental noise on the incidence of colorectal cancer

	ROAD TRAFFIC NOISE (1 STUDY)			RAILWAY NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade	Direct comparison; same PECCO	Indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality			Low quality

Table 20 GRADE for the quality of the evidence for effects of environmental noise on the incidence of prostate cancer

	ROAD TRAFFIC NOISE (1 STUDY)			RAILWAY NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade	Direct comparison; same PECCO	Indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality			Low quality

Table 21 GRADE for the quality of the evidence for effects of environmental noise on the incidence of Non-Hodgkin lymphoma

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

10.3 Annex 3: Dementia and Other Neurodegenerative Outcomes

Table 22 Dementia and other neurodegenerative outcomes: Risk of Bias

Reference	Bias due Exposure Assessment	Bias due to Confounding	Bias due to Selection of Participants	Bias due to Health Outcome Assessment	Bias due to Not Blinded Outcome Assessment	
Andersson et al., Environmental Research, 2018	Low	Low	Unclear	Low	Low	Unclear
Carey et al., BMJ Open, 2018	Low	Low	Low	Low	Low	Low
Culqui et al., Science of Total Environment, 2017	Low	High	Low	Low	Low	Unclear
Linares et al., Environ Res.,2017	Low	High	Low	Low	Low	Unclear
Tzivian et al., Environmental Health Perspectives, 2016	Low	Low	Unclear	Low	Low	Unclear
Diaz et al., Gac Sanit, 2018	Low	High	Low	Low	Low	Unclear
Carmona et al., Science of Total Environment, 2017	Low	High	Low	Low	Low	Unclear

Table 23 GRADE for the quality of evidence of environmental noise being associated with dementia and neurodegenerative outcomes: incidence of vascular dementia

	ROAD TRAFFIC NOISE (2 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study longitudinal & one study retrospective-case control	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

Table 24 GRADE for the quality of evidence of environmental noise being associated with dementia and neurodegenerative outcomes: dementia-related emergency hospital admissions

	ROAD TRAFFIC NOISE (2 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Both studies longitudinal	High quality
1. Study Design	Study quality & bias	Unclear or high risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very Low quality

Table 25 GRADE for the quality of evidence of environmental noise being associated with dementia and neurodegenerative outcomes: cognitive assessment for dementia symptoms

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study cross-sectional	Low quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very Low quality

Table 26 GRADE for the quality of evidence of environmental noise being associated with dementia and neurodegenerative outcomes: multiple sclerosis-related hospital admissions

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study longitudinal	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Unable to assess consistency	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very Low quality

Table 27 GRADE for the quality of evidence of environmental noise being associated with dementia and neurodegenerative outcomes: Parkinson's Disease related hospital admissions and Parkinson's Disease healthcare use (the table is relevant for both outcomes)

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One study longitudinal	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Unable to assess consistency	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very Low quality

10.4 Annex 4: Birth and Reproductive Outcomes

Table 28 Birth and reproductive outcomes: Risk of Bias

Reference	Bias due Exposure Assessment	Bias due to Confounding	Bias due to Selection of Participants	Bias due to Health Outcome Assessment	Bias due to Not Blinded Outcome Assessment	Total Risk of Bias
Hjortebjerg et al., Scand J Work Environ Health, 2018	Low	Low	Low	Low	Low	Low
Min & Min, Environ Pollut., 2017	Low	Low	Low	Low	Low	Low
Pedersen et al., Environ Res., 2017	Low	Low	Low	Low	Low	Low
Smith et al., BMJ, 2017	Low	Low	Low	Low	Low	Low
Wallas et al., Environ Res., 2019	Low	Low	Low	Low	Low	Low
Poulsen et al., Environ Res., 2018	Low	Low	Low	Low	Low	Low
Dzhamov et al., Sci Tot Envt., 2019	Low	Low	Low	Low	Low	Low

Table 29 GRADE for the quality of evidence of environmental noise being associated with low birth weight

	ROAD TRAFFIC NOISE (3 STUDIES)			WIND TURBINE NOISE (1 STUDY)			RAILWAY NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	Cross-sectional evidence	Low quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Consistent evidence; I2 not assessed	No downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			High quality			Moderate quality			Very low quality

Table 30 GRADE for the quality of evidence of environmental noise being associated with pre-term birth

	WIND TURBINE NOISE (1 STUDY)			ROAD NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	Cross-sectional evidence	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Moderate quality			Moderate quality

Table 31 GRADE for the quality of evidence of environmental noise being associated with being small for gestational age

	ROAD NOISE (2 STUDIES)			WIND TURBINE NOISE (1 STUDY)			RAIL NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional evidence	High quality	Intervention/ Longitudinal	All studies longitudinal	High quality	Intervention/ Longitudinal	Cross-sectional evidence	Low quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Moderate quality			Moderate quality			Very low quality

Table 32 GRADE for the quality of evidence of environmental noise being associated with congenital abnormalities

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

Table 33 GRADE for the quality of evidence of environmental noise being associated with febrile seizures

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

Table 34 GRADE for the quality of evidence of environmental noise being associated with male infertility

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	All studies longitudinal	High quality
1. Study Design	Study quality & bias	Low risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

10.5 Annex 5: Cognition

Table 35 Cognition: Risk of Bias

Reference	Bias due Exposure Assessment	Bias due to Confounding	Bias due to Selection of Participants	Bias due to Health Outcome Assessment	Bias due to Not Blinded Outcome Assessment	Total Risk of Bias
Papanikolaou et al., Int J Adolesc Med Health, 2015	Unclear	High	Unclear	Low	Low	High
Seabi et al, J Expo Sci Environ Epidemiol., 2015	Low	Low	High	Low	Low	Unclear
Tzivian et al., Environ Health Perspectives, 2016	Low	Low	Low	Low	Low	Low
Tzivian et al., J Toxicol Environ Health A, 2017	Low	Low	Low	Low	Low	Low
Klatte et al., Environ & Behavior, 2016	Low	Low	Low	Low	Low	Low
Spilski et al., ICBEN, 2017	Low	Low	Low	Low	Low	Low
Spilski et al., Internoise, 2017	Low	Low	Low	Low	Low	Low
Eagen et al., Transport Research Board, 2017	Low	High	High	High	Unclear	High
Foraster et al., Internoise, 2017	Low	Low	Unclear	Low	Low	Unclear

Table 36 GRADE for the quality of evidence of environmental noise being associated with cognition: reading comprehension

	AIRCRAFT NOISE (4 STUDIES)			ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One longitudinal	High quality	Intervention/ Longitudinal	Cross-sectional study	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade	Study quality & bias	High risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality			Very low quality

Table 37 GRADE for the quality of evidence of environmental noise being associated with cognition: mathematics

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional study	Low quality
1. Study Design	Study quality & bias	High risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	Downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

Table 38 GRADE for the quality of evidence of environmental noise being associated with cognition: student distraction

	AIRCRAFT NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	One cross-sectional study	Low quality
1. Study Design	Study quality & bias	High risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

Table 39 GRADE for the quality of evidence of environmental noise being associated with cognition: adult tests of cognition

	ROAD TRAFFIC NOISE (2 STUDIES)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Cross-sectional study	Low quality
1. Study Design	Study quality & bias	High risk of bias	No downgrade
2. Inconsistency	Conflicting results; high I2	Inconsistent evidence; I2 not assessed	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Very low quality

Table 40 GRADE for the quality of evidence of environmental noise being associated with cognition: tests of working memory and attention in children (assessment relevant for both individual assessments)

	ROAD TRAFFIC NOISE (1 STUDY)		
Domains	Criterion	Assessment	Downgrading
Start Level	Intervention/ Longitudinal	Longitudinal	High quality
1. Study Design	Study quality & bias	Unclear risk of bias	Downgrade
2. Inconsistency	Conflicting results; high I2	Unable to assess	Downgrade
3. Indirectness	Direct comparison; same PECCO	No indirect comparisons made.	No downgrade
4. Precision	Confidence interval contains 25% harm or benefit	Unable to rate for narrative review	No downgrade
5. Publication Bias	Funnel plot indicates	Suspected but unable to rate for narrative review	No downgrade
Overall Judgement			Low quality

10.6 Annex 6: Excluded papers

Table 41 Excluded Papers and reasons for exclusion

	Reason for exclusions
Mental Health	
1. Dzhambov, A., Hartig, T., Markevych, I., Tilov, B., & Dimitrova, D. (2018). Urban residential greenspace and mental health in youth: Different approaches to testing multiple pathways yield different conclusions. *Environmental Research, 160*, 47-59.	Does not report association between noise exposure and mental health
2. Gascon, M., Sanchez-Benavides, G., Dadvand, P., Martinez, D., Gramunt, N., Gotsens, X., . . . Nieuwenhuijsen, M. (2018). Long-term exposure to residential green and blue spaces and anxiety and depression in adults: A cross-sectional study. *Environmental Research, 162*, 231-239.	Does not report association between noise exposure and mental health
3. Xiao, J., Li, X., & Zhang, Z. (2016). DALY-Based Health Risk Assessment of Construction Noise in Beijing, China. International Journal of Environmental Research and Public Health, 13(11). doi:10.3390/ijerph13111045	Does not directly measure noise
4. Taskaya, S. (2018). Environmental quality and well-being level in Turkey. Environmental Science and Pollution Research International, 25(28), 27935-27944. doi:10.1007/s11356-018-2806-4	Does not directly measure noise
5. Ma, J., Li, C., Kwan, M. P., & Chai, Y. (2018). A Multilevel Analysis of Perceived Noise Pollution, Geographic Contexts and Mental Health in Beijing. International Journal of Environmental Research and Public Health, 15(7). doi:10.3390/ijerph15071479	Does not directly measure noise
6. Kamimura, A., Armenta, B., Nourian, M., Assasnik, N., Nourian, K., & Chernenko, A. (2017). Perceived Environmental Pollution and Its Impact on Health in China, Japan, and South Korea. Journal of Preventive Medicine and Public Health. Yebang Uihakhoe Chi, 50(3), 188-194. doi:10.3961/jpmph.17.044	Does not directly measure noise

7. Hammersen, F., Niemann, H., & Hoebel, J. (2016). Environmental Noise Annoyance and Mental Health in Adults: Findings from the Cross-Sectional German Health Update (GEDA) Study 2012. International Journal of Environmental Research and Public Health, 13(10). doi:10.3390/ijerph13100954	Does not directly measure noise
8. Dreger, S., Meyer, N., Fromme, H., & Bolte, G. (2015). Environmental noise and incident mental health problems: a prospective cohort study among school children in Germany. Environmental Research, 143, 49-54.	Does not directly measure noise
9. Pun, V. C., Manjourides, J., & Suh, H. H. (2019). Close proximity to roadway and urbanicity associated with mental ill-health in older adults. Science of the Total Environment, 658, 854-860. doi:10.1016/j.scitotenv.2018.12.221	Does not directly measure noise
10. Skrzypek, M., Kowalska, M., Czech, E. M., Niewiadomska, E., & Zejda, J. E. (2017). Impact of road traffic noise on sleep disturbances and attention disorders amongst school children living in Upper Silesian Industrial Zone, Poland. International Journal of Occupational Medicine and Environmental Health, 30(3), 511-520. doi:10.13075/ijomeh.1896.00823	Does not directly measure noise
Dementia and other neurodegenerative outcomes	
1. Chen, H., Kwong, J. C., Copes, R., Hystad, P., van Donkelaar, A., Tu, K., . . . Burnett, R. T. (2017). Exposure to ambient air pollution and the incidence of dementia: A population-based cohort study. *Environment International, 108*, 271-277.	Does not report association between noise exposure and mental health
2. Chen, H., Kwong, J. C., Copes, R., Tu, K., Villeneuve, P. J., van Donkelaar, A., . . . Burnett, R. T. (2017). Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. *Lancet, 389*(10070), 718-726.	Does not measure noise exposure: measures distance to road
Birth and fertility outcomes	
1. Robinson, O., Tamayo, I., de Castro, M., Valentin, A., Giorgis-Allemand, L., Hjertager Krog, N., . . . Basagana, X. (2018). The Urban Exposome during Pregnancy and Its Socioeconomic Determinants. *Environmental Health Perspectives, 126*(7), 077005.	Does not report a relevant health outcome

2. He, S., Smargiassi, A., Low, N., Bilodeau-Bertrand, M., Ayoub, A., & Auger, N. (2019). Residential noise exposure and the longitudinal risk of hospitalization for depression after pregnancy: Postpartum and beyond. *Environmental Research, 170*, 26-32.	Does not report a relevant health outcome: moved to the mental health review.
3. Nassan, F. L., Chavarro, J. E., Minguez-Alarcon, L., Williams, P. L., Tanrikut, C., Ford, J. B., . . . Gaskins, A. J. (2018). Residential distance to major roadways and semen quality, sperm DNA integrity, chromosomal disomy, and serum reproductive hormones among men attending a fertility clinic. International Journal of Hygiene and Environmental Health, 221(5), 830-837.	Does not measure noise exposure: measures distance to road
Cancer	
1. Hvidtfeldt, U. A., Sorensen, M., Geels, C., Ketzel, M., Khan, J., Tjonneland, A., . . . Raaschou-Nielsen, O. (2019). Long-term residential exposure to PM2.5, PM10, black carbon, NO2, and ozone and mortality in a Danish cohort. *Environment International, 123*, 265-272.	Does not report a relevant health outcome
2. James, P., Hart, J. E., Banay, R. F., & Laden, F. (2016). Exposure to Greenness and Mortality in a Nationwide Prospective Cohort Study of Women. *Environmental Health Perspectives, 124*(9), 1344-1352.	Does not report noise exposure
3. Roswall, N., Andersen, Z. J., von Euler-Chelpin, M., Vejborg, I., Lynge, E., Jensen, S. S., . . . Sorensen, M. (2018). Residential traffic noise and mammographic breast density in the Diet, Cancer, and Health cohort. Cancer Causes and Control, 29(4-5), 399-404. doi:10.1007/s10552-018-1021-4	Does not report a relevant health outcome – reports a risk factor for breast cancer not cancer per se.
Cognition	
1. Van Aart, C. J. C., Michels, N., Sioen, I., De Decker, A., Bijnens, E. M., Janssen, B. G., . . . Nawrot, T. S. (2018). Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. *Environment International, 120*, 456-463.	Does not report a relevant cognitive outcome. Does report mental health but was already identified in the mental health review.
2. Braat-Eggen, P. E., van Heijst, A., Hornikx, M., & Kohlrausch, A. (2017). Noise disturbance in open-plan study environments: a field study on noise sources, student tasks and room acoustic parameters. *Ergonomics, 60*(9), 1297-1314.	Experimental study

3. Connolly, D., Dockrell, J., Shield, B., Conetta, R., Mydlarz, C., & Cox, T. (2019). The effects of classroom noise on the reading comprehension of adolescents. *Journal of the Acoustical Society of America, 145*(1), 372.	Experimental study
4. Forns, J., Dadvand, P., Foraster, M., Alvarez-Pedrerol, M., Rivas, I., López-Vicente, M., . . . Sunyer, J. (2016). Traffic-related air pollution, noise at school and behavioural problems in Barcelona schoolchildren: a cross-sectional study. *Environmental Health Perspectives, 124*(4), 529-535	Does not report a relevant cognitive outcome. Moved to mental health review.
5. Silva, L. T., Oliveria, I. S., & Silva, J. F. (2016). The impact of urban noise on primary schools. Perceptive evaluation and objective assessment. Applied Acoustics, 106, 2-9.	Does not report a relevant cognitive outcome. Reports attitudes to noise.
6. Onchang, R., & Hawker, D. W. (2018). Community noise exposure and annoyance, activity interference, and academic achievement among university students. Noise Health, 20(94), 69-76.	Does not report on noise exposure and grade point average (reports on the association for noise annoyance)

10.7 Annex 7: Search terms

10.7.1 The following search terms were entered into the Pubmed database searches:

Study terms:

- longitudinal study or studies
- prospective study or studies
- retrospective study or studies
- ecological study or studies
- cohort study or studies
- case study or studies
- crosssectional or cross-sectional study or studies

Noise terms:

- noise
- motorcycle or motorcycles and noise
- environment or environmental noise
- residence characteristics or community noise
- traffic noise
- road noise
- motor vehicle noise
- aircraft noise
- airport noise
- railway noise
- industry noise or industrial noise
- build*[16] noise
- vent* noise

[16] * is a wildcard term that searches the database for all variants of the words ending – e.g. for build* the search would look for building, build, builder etc.

- mechanic* and service noise
- air and condition* noise
- neighbour*/neighbor* noise
- train noise
- transportation noise
- leisure activities/leisure time and noise
- low frequency noise
- classroom or schools noise
- combined noise
- nuisance noise
- air pollution and noise
- household noise
- wind turbine noise/wind farm noise

Dementia terms

- dementia
- Vascular dementia
- Alzheimer's disease or Alzheimer disease
- Lewy bodies dementia
- Frontotemporal dementia

Cancer terms

- cancer
- neoplasm
- carcinoma
- sarcoma
- myeloma
- leukaemia
- lymphoma

Birth outcomes

- Birth weight
- Pregnancy
- Fetus/foetus
- Preterm
- Gestation
- Infertility
- Sterile
- Malformation
- Birth
- Labor/labour
- Prenatal
- Perinatal
- Fert* or Infert*

Mental health, wellbeing and quality of life

- mental health
- emotions or emotional disease/disorder
- psychological diagnosis or symptoms
- mental disorders
- psychiatric disorders
- conduct disorder
- anxiety
- depressive disorder or depression
- health status
- wellbeing or well being or well-being
- personal satisfaction
- quality of life
- behavioural or behavioural issues
- helplessness

- strengths and difficulties questionnaire
- kindl
- hrqol
- whoqol
- General health questionnaire or GHQ
- health surveys
- Short Form-36 or SF-36

Cognition

- Executive function
- Working memory
- Reasoning
- Task flexibilit*
- Problem solv*
- Hyperactiv*
- Concentr*
- Speech intelligibilit*
- Impair*
- Standardised assess* or standardized assess*
- SATS/Sats
- Reading
- Reading comprehension
- Oral comprehension
- Memory
- Attention
- Learn impair*

10.7.2 Due to time constraints and the breadth of the PubMed database searches, the Science Direct searches used a sub-set of these search terms to try and identify papers that had not been already identified.

The Science Direct searches focused on aircraft noise, road traffic noise, railway noise and wind-turbine noise for each health outcome.

10.8 Annex 8: Extraction tables

Table 42 Mental health, wellbeing and quality of life extraction table

Reference	Study Design	Population	Exposure	Comparator	Confounding	Outcome	Findings
Weyde, Envt Health, 2017	Cohort study	Based on the Norwegian Mother and Child Cohort Study. Pregnancy sample: n=1934. Postnatal sample: (n=1384)	Road and rail traffic noise exposure was modelled using the Nordic Prediction Method	Less than or equal to Lden 30dB	Household income, urbanity, maternal education, ethnicity, maternal alcohol consumption and smoking during pregnancy, low birthweight	Inattention in 8-year old as reported by mothers	An association with inattention at age 8 years was found for road traffic noise exposure at age 8 years (coef = .0083, CI = [.0012, .0154]; 1.2% point increase in inattention score per 10 dB increase in noise level)
Feder et al., Environ Res, 2015	Cross sectional	Randomly selected participants aged 18–79 (606 males, 632 females)	Outdoor wind turbine sound pressure levels were estimated at each dwelling using both ISO9613-1and ISO9613-2(ISO 1993,1996) as incorporated in the commercial software Cadna Aversion	4 dB	Provincial differences	Quality of life, assessed using the WHOQOL-BREF	Wind turbine noise levels were not found to be related to scores on the Physical,Psychological,Social or Environment domains, or to rated QOL and Satisfaction with Health questions

Seidler et al., Environ Res, 2017	Case control	Individuals aged ≥40 years living in the region of Frankfurt International airport	Address-specific exposure to aircraft, road and railway traffic noise in 2005 was estimated	<40 dB	Age, sex, urban living environment and the local proportion of people receiving unemployment benefit as an indicator of socio-economic status	Diagnoses of depression	For road traffic noise, a linear exposure-risk relationship was found for 24-h continuous sound levels ≥70 dB. For aircraft noise, the risk estimates reached a maximum at 50–55 dB and decreased at higher exposure categories. For railway noise, risk estimates peaked at 60–65 dB
Welch et al., Noise Health, 2018	Case control	Residents aged >18 of Wellington city, New Zealand	Residents living within 250 meters of Wellington airport and within 65 Db Ldn contour (Airport Group) or living in a socioeconomically matched Wellington suburb (non-airport group)	65 dB	Sex, age, education, employment status, current illness, noise sensitivity	Noise sensitivity – measured using a self-rated three-point scale	People were found to have a significantly poorer Health related QOL than others when they lived near an airport, but not when they lived in the control area
Klatte et al., Environ & Behavior, 2016	Secondary analysis of the NORAH dataset	1,243 second graders from 29 schools around Frankfurt/Main Airport in Germany	Aircraft noise levels were calculated on the basis of radar data from the Flight Track and Aircraft Noise Monitoring System provided by German Air Traffic Services. Road traffic and railway noise levels were estimated using a combination of information provided by local authorities	39 dB	Age, gender, non-verbal abilities, SES, migration background, number of children's books at home, German language proficiency, percentage of children with a migration background in the class, mean SES, class size, and parental involvement, classroom insulation, road-traffic noise, and railway noise at school	Parent ratings of children's quality of life and children's wellbeing in school	Increasing exposure was linearly associated with less positive ratings of quality of life, increasing noise annoyance, and decreasing reading performance. A 20 dB increase in aircraft noise exposure was associated with a decrease in reading scores of one fifth of a standard deviation, corresponding to a reading delay of about 2 months
Dzhambov et al., Environ Res, 2018a	Cross sectional	720 students aged 18-35 years, residing in Plovdiv	Residential noise exposure (LAeq; day equivalent noise level) was obtained by applying a land use regression (LUR) model	62.4 - 73.5 dB	Sex, age, ethnicity, duration of residence, time spent at home/day, and stressful life events	Mental health measured using General Health Questionnaire (GHQ-12)	Evidence that increased residential noise was related to mental ill-health through several indirect pathways

Generaal et al., Psychol Med, 2019	Cross sectional	2980 participants with and without depressive and anxiety disorders in the past year	Daily mean noise of road- rail- and air traffic for several years were modelled by the Netherlands Environmental Assessment Agency by using the Empara Noise tool	N.A	Age, sex, years of education and household income	The presence of current diagnoses of depressive disorders and anxiety disorders	Neighbourhood socioeconomic factors, physical factors (high levels of traffic noise) and social factors (lower social cohesion and less safety) were associated with the presence of depressive and anxiety disorders
Dzhambov et al., Environ Res, 2018b	Cross-sectional	720 students aged 18-35 years, residing in Plovdiv	Residential noise exposure (LAeq; day equivalent noise level) was obtained by applying a land use regression (LUR) model	N.A	Age, sex, ethnicity, individual level, economic status, duration of residence, time spent at home/day, population, and month of data collection	Mental health measured using General Health Questionnaire (GHQ-12)	Evidence that having more greenspace near the residence supported mental health through several indirect pathways with serial components
Dzhambov et al., Environ Int., 2017	Cross sectional	399 students aged 15–25 years, recruited from two high schools and three universities in Plovdiv	Road traffic noise exposure (Lden) was derived from the strategic noise map of Plovdiv	50 dB	Sex, age, ethnicity, socioeconomic status and noise sensitivity	Mental health measured using General Health Questionnaire (GHQ-12)	higher noise exposure was associated with worse mental health only indirectly
Zock et al., Environ Int., 2018	Cross sectional	4450 registered patients of Dutch GPs who were living in 2013 in one of the 181 five-digit postal code areas in the Netherlands	Exposure to road traffic noise and railway noise was estimated by applying the Standard Model Instrumentation for Noise Assessments	N.A	Sex, age, household income, and socio-economic status and municipality and neighbourhood	Diagnosed (co)morbidity and registered symptoms - coded following the International Classification of Primary Care	A high diversity in land use of neighbourhoods may be beneficial for physical and mental health of the inhabitants
Lim et al., Noise Health, 2018	Population-based study	918 elementary and middle-school students in South Korea	The level of road traffic noise at the exterior wall of a residential building was calculated using noise prediction software based on a noise map	N.A	Age, sex, income, premature birth, maternal age at birth, maternal disease during pregnancy, passive smoking, mental disorders	Mental health in childhood	Noise sensitivity was significantly associated with internalizing, externalizing, and total behavioural problems
Onchang et al., Noise Health, 2018	Cross sectional	Student group residing off campus (n= 450) and a control group residing in dormitories on-campus (n=336)	Noise levels at both on-campus and off-campus locations were measured using sound level meters	N.A	No adjustments made	GPA score	Various contemporary community noise sources affect university students' activities and possibly influence their educational achievement as well

Forns et al., Enviro Health Perspectives, 2016	Cross sectional	Children aged 7-11 years in Barcelona during 2012-13	Noise levels inside the classroom were measured during the second 1-week air pollution sampling period	N.A	Child's sex, child's age, black carbon concentrations at home, traffic noise annoyance at home, home tobacco use, indicators of SES at the individual level and the area level	Total ADHD symptomatology	Noise was significantly associated with ADHD-DSM-IV scores
He et al., Environ Res., 2019	Cohort study	140,456 pregnant women with no documented history of mental illness, who residing in Montreal	Three indicators of noise exposure were used including A-weighted total outdoor noise (LAeq. 24 h), day-evening-night equivalent noise (Lden), and nighttime noise (Lnight)	50 dB	Maternal age, parity, multiple pregnancy, stillbirth, comorbidity, socioeconomic deprivation, neighbourhood walkability and time period	Hospitalizations for depression or other mental disorders	Compared with 50 dB(A), an LAeq. 24 h of 60 dB(A) was associated with 1.16 times (95% CI 0.84–1.62) the risk of depression hospitalization, and 1.34 times (95% CI 1.04–1.74) the risk of other mental disorders
Civil Aviation Authority, 2017 (Survey of Noise Attitudes)	Cross-sectional study	1877 adult participants living near Birmingham; East Midlands; Gatwick; Heathrow; London City; Luton; Manchester; Newcastle; Stansted airports	Respondents were selected based on exposure of 51dB LAeq16 hour (92-day average) or higher for summer 2013 using published noise contour data for the airport	Sampling was stratified so that one-third of the sample was exposed to 51-54dB LAeq16 hour, and two-thirds were exposed to >54dB LAeq16 hour	None	Warwick Edinburgh Mental Wellbeing Scale and self-reported health	Found no association between aircraft noise (LAeq 16h 92 day) and wellbeing or self-reported health
Klompmaker et al., 2019, Environment International	Cross sectional	National public health survey in Netherlands which includes information on 387,195 citizens, aged ≥19 years	Residential traffic noise levels were estimated by the Standard Model Instrumentation for Noise Assessments	N.A	Age, sex, marital status, region of origin, paid occupation, household income, level of education, neighbourhood SES, smoking status, alcohol use, degree of urbanization	Mental health, measured using the Dutch national health survey	Road-traffic noise was only positively associated with prescription of anxiolytics, while rail-traffic noise was only positively associated with psychological distress
Enembe et al., 2018, Environmental International	Cross sectional	Eight-thousand Helsinki residents ag 25 years and above were selected from the Population Registry of Finland	Residential exposure to road-traffic noise was estimated from façade noise maps	<45 dB	Sex, age, marital status, employment status, household income, alcohol intake, current smoking status, level of physical activity, pet ownership and sleep disturbance	Use of sleep medication, anxiolytics and antidepressants	Noise annoyance was associated with anxiolytic drug use, OR=1.41 (95% CI: 1.02–1.95), but not with sedative or antidepressant use. There was suggestive association between modelled noise at levels higher than 60 dB and anxiolytic or antidepressant use
Oiamo et al., 2015, Social Science and Medicine	Cross sectional	603 individuals that were exposed to traffic noise and air pollution	Residential levels of traffic noise were	N.A	Sex & age	Health related quality of life measured by	Noise annoyance had a significant and negative effect on both mental and physical health factors of the

		in Windsor, Ontario, Canada	modelled in SoundPLAN 7.3			the SF-12 health survey	SF-12 and there was a significant covariance between noise annoyance and odour annoyance
Leijssen et al., 2019, International Journal of Hygience and Environmental Health	Cross sectional	23,293 participants, aged 18-70 years, living in Amsterdam between 2011 and 2015	Modelled daily average noise levels on road-traffic for the year 2011 in the Netherlands using the Empara Noisetool	45 dB	Age, sex, educational level, occupational status, ethnic origin, marital status, household composition, neuroticism, stressful life events, neighbourhood-level, including socioeconomic status, blue/green space and liveability	Depressed mood	Exposure to ≥70 dB(A) compared to the reference group of 45–54 dB(A) showed a significant positive association with depressed mood (OR: 1.65, 95% CI 1.10, 2.48)
Zijlema et al., 2015, Int. Journal of Hygiene and Environmental Health	Cross sectional	5,304 participants, aged between 18-92 years, in the Netherlands	Road traffic noise was estimated using a new implementation of the CNOSSOS-EU noise modelling framework	N.A	Sex, age, educational level and household equivalent income, hostility and vulnerability to stress	Somatic symptoms	No association of noise exposure and somatic symptoms (incidence rate ratio (IRR) 1.001; 95% confidence interval (CI) 1.000–1.001; n = 56,937)
Wallas et al., 2018, Int. Journal of Hygiene and Environmental Health	Cross sectional	1751 adolescents from the BAMSE birth cohort based in Stockholm County, between 1994-1996	Traffic noise exposure assessment was performed using data from several national, regional and local authorities	<45 dB	Age, sex, rhinitis, eczema and sampling season	Saliva cortisol levels	Road traffic noise exposure was not associated with saliva cortisol, however, annoyance to noise tended to increase the levels. Saliva cortisol levels appeared particularly high among those who were highly annoyed and exposed to road traffic noise levels≥55 dB Lden
Lawton et al., 2016, Transportation Research Part D	Cross sectional	Two-year sample of nearly 190,000 households, from the Annual Population Survey, UK	Noise contour data were derived from annual average noise levels from 2012 airport operator strategic noise maps at the geographical level of residential dwelling outer area	55 dB	Ethnicity, household income, health status, marital status, employment status, housing status, gender, age, geographic region, religion, and education	Subjective wellbeing	The presence of daytime aviation noise was found to consistently negatively impact on five subjective wellbeing measures
Wright et al. 2018, Environmental Health	Cross sectional	198,532 people enumerated at the 2011 Census, aged 18 years and over and living within the 54 dB Belfast City Airport noise contour	Residential exposure to aircraft noise (LAeq,16h) was assessed by linking Census records with modelled noise contours surrounding George Best Belfast City Airport	54 dB	Age, sex, ethnicity, religion and marital status, education, property value and car availability, likelihood of poor mental	Prevalence of self-assessed mental ill health	No association between aircraft noise and risk of mental ill health

Van Aart et al., Environ Int., 2018	Longitudinal	172 Belgian children aged 6.7-12.2, followed for three years (2012-2015)	A GIS-based noise model including the Flemish street and railway networks was used to estimate traffic noise levels in 5 dB(A)-intervals according to the European Noise Directive (2002/49/EC)	N.A	Age, sex & socioeconomic status	Childhood psychosocial stress – Strengths and Difficulties questionnaire and hair cortisol	Inverse association between residential and traffic density with hyperactivity problems

Table 43 Cancer extraction table

Reference	Study Design	Population	Exposure	Comparator	Confounding	Outcome	Findings
Andersen et al., Lynge Breast Cancer Res, 2018	Longitudinal cohort study	22,466 female nurses (age > 44 years) who at recruitment in 1993 or 1999 reported information on breast cancer risk factors	**Road traffic noise levels at the nurseroad traffic noise levels at the nurses' residential addresses were calculated using the Nord2000**	<48 dB	Age, birth cohort, body mass index, alcohol use, leisure time physical activity, smoking status, age at menarche, parity (yes; no), number of children, age at first birth, menopausal status, HT use, and oral contraceptive use	Incidence of breast cancer	For each 10 dB increase in 24-year mean noise levels at their residence, a statistically significant 10% increase in total breast cancer incidence was found
Hegewald et al., Scandinavian J Work Envt Health, 2017	Prospective	1,026 ,670 Women aged ≥40 years by 2010 living in the region surrounding the Frankfurt international airport	Aircraft noises, road traffic noise and rail noise were all modelled using SoundPLan.	<40 dB	Age, hormone replacement therapy, and regional proportion of people receiving unemployment benefits	Incident diagnoses of breast cancer	An increased odds ratio was observed for estrogen receptor negative tumours at 24-hour aircraft noise levels 55–59 dB [OR 55–59 dB 1.41. Clear associations between road and rail traffic noise were not observed
Roswall et al., Environ Reseasrch, 2016	Longitudinal cohort study	57,053 participants (29,875 women) aged 50-64 years of age residing in Copenhagen	Residential road traffic noise was calculated as the equivalent continuous A-weights sound pressure level (LAeq)	N.A	Calendar year at diagnosis, train noise, smoking, alcohol intake, abstainers, waist circumference, recreational physical activity and marital status	Overall mortality and breast cancer-specific mortality	No association was found between time-weighted averages of residential road traffic noise 1-,3- or 5- years before death and overall or breast cancer-specific mortality

Roswall, et al., Cancer, Causes & Control, 2017	Longitudinal cohort study	57,053 participants (29,875 women) aged 50-64 years of age residing in Copenhagen	Traffic noise was calculated for all residential addresses from 1987 to 2012 for 51,283 Danes in the Diet, Cancer and Health Cohort. Railway noise also calculated.	<40 dB	Age, sex, railway noise, smoking, smoking duration, smoking intensity, alcohol intake, abstainers. recreational physical activity, education, whole grain cereal, red meat, and marital status, income and municipal-level population density at baseline	Overall colorectal cancer incidence	No association found between residential road traffic noise and rectal cancer. Observed an association with distal colon cancer, but not for proximal colon cancer: 0.99 (0.83–1.18), per 10 dB, 10 years preceding diagnosis. There was no association between railway noise and colorectal cancer, or any subtype
Roswall et al., PloS One, 2015	Longitudinal cohort study	27,178 men aged 50-65 years born in Denmark with no previous cancer diagnosis and living in Greater Copenhagen	Road and railway traffic was calculated using SoundPLAN	N.A	Education level, area level socioeconomic position of baseline municipalities or districts for Copenhagen municipality based on municipality/district information on education; work market affiliation; income; smoking status; smoking duration; body mass index; waist circumference; physical activity; calendar year; and airport noise	Incidence rate ratios for association between road traffic and railway noise and prostate cancer	There was no association between residential road traffic noise and risk of prostate cancer for any of the three exposure windows. For railway noise, there was no association with overall prostate cancer
Roswall et al., PloS One, 2017	Longitudinal cohort study	57,053 participants (29,875 women) aged 50-64 years of age residing in Copenhagen	Road and railway traffic was calculated using SoundPLAN	N.A	Age, calendar year of diagnosis and sex, railway noise at diagnosis, baseline smoking status, baseline smoking duration, baseline alcohol intake, baseline abstainers, baseline red meat intake, baseline recreational physical activity, education 1 year before diagnosis and income 1 year before diagnosis	Overall mortality and colorectal cancer-specific mortality	No association was found between road traffic noise and overall (MRR 1.00 (0.88-1.13) per 10dB) or colorectal cancer – specific mortality (MRR 0.98 (0.85-1.13) per 10 dB) over the entire follow-up period, or 1 years preceding death Railway noise was only included as a covariate

Sorensen et al., I J of Cancer, 2014	Longitudinal cohort study	(29,875 women) aged 50-64 years of age residing in Copenhagen	Road traffic and railway traffic noise exposure were calculated using SoundPLAN	<42 dB	Age, parity, age at first birth, hormone replacement therapy status and duration, age at menarche, length of school attendance, BMI, alcohol consumption, alcohol intake, smoking status, intake of vegetables, physical activity, calendar-year and railways and airport noise	Incidence rate ratios (IRRs) for breast cancer in association with road traffic and railway noise	No overall association was found between residential road traffic or railway noise and breast cancer risk. Among women with estrogen receptor negative breast cancer, a 10-dB higher level of road traffic noise during the previous 1, 5 and 10 years were associated with 28%, 23% and 20% higher risks of estrogen receptor negative breast cancer. Similarly, a 10-dB increase in railway noise increased risk for estrogen receptor negative breast cancer by 38%. No association was found between road traffic or railway noise and estrogen receptor positive breast cancer
Sorensen et al., Environmental Research, 2015	Case control	2753 Cases were identified using the Cancer Registry. Eligible cases were Danes between 30 and 84 years of age with a primary diagnosis of NHL between 1992 and 2010. For each case, two random controls, matched on sex and year of birth were selected from the Civil Registration System	Road traffic noise exposure was calculated at the most exposed façade for all present and historical addresses using Sound PLAN	55 dB	Age and sex, education, disposable income, cohabitation status, Charlson comorbidity index, air pollution	Odds ratios and 95% confidence internals for risk for non-hodgkin lymphoma associated with exposure to traffic noise	A 5—year time-weighted mean of road traffic noise about 65dB was associated with an 18% higher risk for non-hodgkin lymphoma (NHL) when compared to road traffic noise below 55dB, whereas for exposure between 55 and 65dB no association was found. In analyses of NHL subtypes, no association was found between road traffic noise and risk of T-cell lymphoma, whereas increased risks for B-cell lymphoma and unspecified lymphomas were observed as exposures above 65dB

Table 44 Dementia and other neurodegenerative outcomes extraction table

Reference	Study Design	Population	Exposure	Comparator	Confounding	Outcome	Findings
Andersson et al., Environmental Research, 2018	Longitudinal cohort study	1721 participants from the Betula project, 985 men and 736 women, who at baseline were aged 55–85 years (mean 68.5 ± 9.4)	Modelled data provided road traffic noise levels (Leq. 24 h) at the participants' residential address at baseline	35 dB	Age, ApoE4, education, physical activity, smoking, sex, alcohol use, BMI, and waist-hip ratio, hypertension, diabetes, and stroke	Dementia incidence	Exposure to noise levels (Leq. 24 h)> 55 dB had no significant effect on dementia risk (HR 0.95; CI: 0.57, 1.57).
Carey et al., BMJ Open, 2018	Retrospective cohort study	130 978 adults aged 50–79 years registered with their general practices on 1 January 2005, with no recorded history of dementia or care home residence	Traffic intensity, distance from major road and night-time noise levels (Lnight) were estimated at the postcode level linked to clinical data via residential postcode. Road traffic noise levels were estimated using the TRAffic Noise EXposure (TRANEX) model	Mean exposure Lnight 52.1dB	Age, sex, ethnicity, smoking and body mass index, area deprivation and comorbidity (IHD, stroke, diabetes, heart failure)	A first recorded diagnosis of dementia and, where specified, subgroups of Alzheimer's disease and vascular dementia during 2005–2013	There was a positive exposure response relationship between dementia and all measures of air pollution except O3. Increases in dementia risk were also observed with PM2.5, PM2.5 specifically from primary traffic sources only and Lnight, but only NO2 and PM2.5
Culqui et al., Science of Total Environment, 2017	Longitudinal ecological time series study	Madrid during the period 2001-2009 – mean population of 3,116,897 and of this total, 754,005 persons (24.2%) were aged 60 years or over	Mean daily noise levels (dB(A)) for equivalent diurnal noise level 7–23 h (Leqd), equivalent nocturnal noise level 23–7 h (Leqn), and daily noise level 24 h (Leq24) were measured	N.A	No adjustments made	Short-term admissions to hospital for Alzheimer's disease (ICD-9 code)	There was no statistically significant association with emergency Alzheimer's disease admissions or noise

Linares et al., Environ Res.,2017	Longitudinl ecological time-series study	Number of daily dementia-related emergency (DDE) hospital admissions to Madrid municipal as obtained from the Hospital Morbidity Survey (National Statistics Institute)	Leqd, equivalent diurnal noise level (from 8 to 22 h), and Leqn, equivalent nocturnal noise level (from 22 to 8 h) in dB(A) was provided by the Madrid Municipal Air Quality Monitoring Grid	N.A		Number of daily dementia-related emergency admissions to municipal hospitals in Madrid	Admissions displayed a linear functional relationship without a threshold in the case of Leqd. The RR of DDE admissions was 1.15 (1.11–1.20) for an increase of 1 dB in Leqd
Diaz J et al., 2017 Gac Sanit	Ecological time series analysis	The population of Madrid during the period 2001-2009, it had a mean population of 3,116,897 and of this total, 284,929 persons (9%) were aged 75 years or over	The Madrid Municipal Air Quality Monitoring Grid supplied Leqd, equivalent diurnal noise level (from 8 to 22 h), and Leqn, equivalent nocturnal noise level	55 dB	Temperature, pollution, trends and seasons	Parkinson's Disease related demand for healthcare	The association between Leqd and Hospital admissions was found to be linear. Leqd and Leqn at lag 0.1 and temperature at lags 1 and 5 were the only environmental variables associated with increased Parkinson's disease related healthcare demand
Carmona et al., 2018 Science of the Total Environment	Longitudinal ecological time series study	The population of Madrid during the period 2001-2009, it had a mean population of 3,116,897	Mean daily noise levels (dB(A)) for equivalent diurnal noise level 7–23 h (Leqd), equivalent nocturnal noise level 23–7 h (Leqn), and daily noise level 24 h (Leq24), supplied by the Madrid Municipal Air Quality Monitoring Grid	N.A	Linear trends, seasonality and the autoregressive nature of the series itself	Number of emergency MS hospital admissions	Traffic noise can exacerbate MS symptoms, leading to hospital admissions due to this cause

Tzivian et al., Environmental Health Perspectives, 2016	Cross-sectional cohort study	4,086 participants who were 50–80 years old	Lden & Lnight – long term exposure at the baseline address (2000-2003)	Lden mean 53.74 (SD+-9.49) Lnight mean 44.88 (SD+-9.17)	Age, sex, socioeconomic status, alcohol consumption, smoking status, self-reported environmental tobacco smoke, any regular physical activity, body mass index	Diagnoses of Mild cognitive impairment (MCI)	A 10 dB(A) increase in LDEN was associated with overall MCI. A 10dB(A) increase in Lnight was associated with overall MCI

Table 45 Birth and reproductive outcomes extraction table

Reference	Study Design	Population	Exposure	Comparator	Confounding	Outcome	Findings
Hjortebjerg et al., Scand J Work Environ Health, 2018	Cohort study	Study based on children enrolled in the Danish National Birth Cohort which consecutively recruited pregnant women from March 1996 to November 2002 from all over Denmark. 57,282 children participated	Estimated annual levels of road traffic and railway noise at all addresses using SoundPLAN	N.A	Age, sex of child, maternal age at birth, parity, smoking during first trimester, alcohol consumption during first trimester, level of education, disposable income one year before birth of the child, road traffic noise for air pollution and vice versa	Children with febrile seizures were identified by linking the unique personal identification number of each child in the study base to the nationwide Danish National Patient Register	An interquartile range increase in childhood exposure to road traffic noise and air pollution was associated with an 11% and 5% higher risk for febrile seizures, respectively, after adjustment for potential confounders
Min KB & Min JY, Environ Pollut, 2017	Population based cohort study	Used the National Health Insurance Service-National Sample Cohort (2002-2013), a population-wide health insurance claims dataset. A total of 206,492 males of reproductive age (20-59 years) with no history of congenital malformations	Data on noise exposure was obtained from the National Noise Information System	35 dB	Age, income, residence area, smoking history, exercise, alcohol use, blood glucose levels, BMI, history of diseases	Diagnoses of male infertility	A non-linear dose-response relationship was observed between infertility and quartiles of daytime and night time noise after adjustment for confounding variables. Based on WHO criteria, adjusted odds for infertility were significantly increased (OR ¼ 1.14; 95% CI, 1.05e1.23) in males exposed to night time noise >55 dB

Pedersen et al., Environ Res., 2017	Cohort study	84,218 liveborn singletons (1997–2002) from the Danish National Birth Cohort	Road traffic noise was calculated at the most exposed facade of each residential address using SoundPLAN	N.A	Maternal smoking, maternal alcohol consumption, parental age (years), maternal education the year before last menstrual period, household disposable income, parity, maternal pre-pregnancy BMI	Diagnoses of congenital anomalies	Residential road traffic exposure to noise or air pollution during pregnancy did not increase risk for development of congenital anomalies
Smith et al., BMJ, 2017	Retrospective population-based cohort study	540,365 singleton term live births	A-weighted road traffic noise levels (dB) were modelled to 0.1 dB resolution for all geocoded maternal residential addresses using the Traffic Noise Exposure (TRANEX) model	50 dB	Maternal age, birth registration type, birth season, birth year, Carstairs deprivation quintile, tobacco expenditure. Birth weight and LBW were adjusted for sex, gestational age and baby's ethnicity	Birth weight outcomes – low birth weight, small for gestational age	Trends of decreasing birth weight across increasing road traffic noise categories were observed, but were strongly attenuated when adjusted for primary traffic related air pollutants
Dzhambov et al., 2019, Science of the Total Environment	Explorative study	Used data from two cross-sectional studies (UIT, n = 573 and BBT, n = 518) in the Tyrol Region (Austria/Italy)	Noise emissions were calculated in 2003/2004.Total day-evening night noise level (Lden) was calculated at the most exposed façade covering road and rail noise	10 dB	sex of child, age of mother at birth, gestational age, single mother status, mother's education, smoking during pregnancy, duration of residence before conception, and house type, Ldn or NO2	Birth outcomes – low birth weight and small for gestational age	An increase of Ldn was associated with higher odds for low birth weight but only in one of the studies. Unexpectedly, an increase in Lden was associated with an increase in the odds for being small for gestational age.

Poulsen et al., 2018, Environmental Research	Nationwide registered based study	135,795 pregnant women living in Danish dwellings from 1982 to 2013	Estimated hourly outdoor and low frequency indoor wind turbine noise at the dwellings of the pregnant women and aggregated as mean night-time Wind turbine noise during pregnancy	>24 dB	Sex, calendar year of birth, maternal age at birth, parity, season of conception, marital status, education, work status, personal income, area-level mean disposable income, ever living on a farm during pregnancy, shortest distance to road with ≥5000 vehicles per day during pregnancy, traffic load within 500m radius of dwelling averaged over all addresses held during pregnancy, maternal smoking during 1st trimester and for both maternal smoking and BMI	Small for gestational age, pre-term birth and birth weight	No association between night-time wind turbine noise and adverse birth outcomes
Wallas et al., Environ Res., 2019	Longitudinal cohort study	4089 children born 1994-1996 in four pre-defined areas of Stockholm County	Road traffic noise levels were estimated at the most exposed façade of all residential homes where the study subjects lived. Maternal occupational noise exposure during pregnancy was estimated based on self-reported occupation	N.A	Parental occupation, smoking during pregnancy, maternal BMI and municipality at birth	Data on BMI from birth to adolescence were collected via questionnaires, clinical examinations and health care records. A national register provided information on birth outcomes	Residential road traffic noise exposure was associated with increases in BMI from school age to adolescence, but not at earlier ages. Maternal noise exposure during pregnancy was generally unrelated to adverse birth outcomes (low birth weight, pre-term birth) and BMI from birth to adolescence in the children, however, traffic noise exposure was associated with a decreased risk of preterm birth

Table 46 Cognition extraction table

Reference	Study Design	Population	Exposure	Comparator	Confounding	Outcome	Findings
Papanikolaou et al., Int J Adolesc Med Health, 2015	Cross sectional	676 participants (324 boys,47.9% and 352 girls, 52.1%) of the 4th and 5th elementary classes	Selected schools on the basis of increasing levels of exposure to road traffic noise and classified into three categories, according to external noise: Low-level noise: 55–66 dB, Medium-level noise: 67–77 dB, and High-level noise: 72–80 dB. Noise levels outside classrooms were measured with an echo meter	55-66 dB	No adjustments made	To assess the effects of noise on cognitive skills, a test was constructed based on the National Curriculum for Elementary Education for reading and mathematics	Children in low-level noise schools showed statistically significant differences from children in medium- and high-level noise schools in reading performance ($p < 0.001$). Children in low-level noise schools differed significantly from children in high-level noise schools but only in mathematics performance ($p = 0.001$)
Tzivian et al., Environ Health Perspectives 2016	Cross sectional	4,814 randomly chosen men and women who were 45–75 years old at baseline, enrolled into the study between December 2000 and August 2003	Long-term exposure to traffic noise was modeled according to the European Directive 2002/49/EC as the weighted 24-hr mean (LDEN) and the night-time mean (LNIGHT) at the baseline address	N.A	Age, sex, socioeconomic status, alcohol consumption, smoking status, self-reported environmental tobacco smoke, any regular physical activity, body mass index, background NO2	Assessment of overall mild cognitive impairment (MCI) and amnestic (aMCI) and nonamnestic (naMCI) mild cognitive impairment	Most air pollutants and traffic noise were associated with overall MCI and aMCI. 10 A-weighted decibel [dB(A)] increase in LDEN was associated with overall MCI

Tzivian et al., J Toxicol Environ Health A, 2017	Cross sectional	4814 randomly chosen men and women aged between 45 and 75 years	Long-term exposure to traffic noise was modeled according to the European Directive 2002/49/EC	N.A	Age, sex, socioeconomic status, alcohol consumption, smoking status, ETS, any regular physical activity, and BMI	Cognitive function – measured through a cognitive performance assessment	High noise exposure increased the association of air pollution with cognitive function. observed stronger negative associations in participants with double exposure compared to the addition of effect estimates of each single exposure
Klatte et al., Environ & Behavior, 2016	Secondary analysis of the NORAH dataset	1,243 second graders from 29 schools around Frankfurt/Main Airport in Germany	Aircraft noise levels were calculated on the basis of radar data from the Flight Track and Aircraft Noise Monitoring System provided by German Air Traffic Services. Road traffic and railway noise levels were estimated using a combination of information provided by local authorities and were used only as covariates	39 dB	Age, gender, non-verbal abilities, SES, migration background, number of children's books at home, German language proficiency, percentage of children with a migration background in the class, mean SES, class size, and parental involvement, classroom insulation, road-traffic noise, and railway noise at school	Reading performance - assessed though a standardised reading comprehension test for primary school children instructed in German	Increasing exposure was linearly associated with less positive ratings of quality of life, increasing noise annoyance, and decreasing reading performance. A 20 dB increase in aircraft noise exposure was associated with a decrease in reading scores of one fifth of a standard deviation, corresponding to a reading delay of about 2 months
Spilski et al., ICBEN, 2017	Cross sectional	1,243 children participated in the study	Exposure levels at schools and at the children's homes were assessed by the NORAH acoustic team. Aircraft noise levels were calculated on the basis of radar data from the Flight Track and Aircraft Noise Monitoring System (FANOMOS), provided by German Air Traffic Services	34 dB	Age, gender, SES, migration background, German language proficiency, number of children's books, non-verbal abilities, story comprehension, phonological awareness, access to phonological representations, class socioeconomic status (SES), class size, percentage of children with a migration background, parental involvement in school affairs, classroom insulation, road-traffic noise, and railroad noise at school	Cognition and quality of life	A 10 dB increase of aircraft noise at school was associated with a decrease in children's global reading and word reading scores by one tenth of a SD - one point on the T-score scale. For text reading, a 10 dB increase of aircraft noise was associated with a decrease by one eighth of a SD. For sentence reading, the effect of aircraft noise did not reach significance, neither in the unadjusted model nor in the adjusted models

Spilski et al., Internoise, 2017	Cross sectional	439 German second-graders from 29 schools in the vicinity of Frankfurt Airport, Germany	Aircraft noise - Noise Exposure levels were calculated on the basis of radar data from the Flight Track and Aircraft Noise Monitoring System (FANOMOS) provided by German Air Traffic Services. Road traffic and railway noise levels were estimated using a combination of information by local authorities	39 dB	Age, gender, SES, number of children's books, non-verbal abilities, story comprehension, phonological awareness, access to phonological representations, class SES, class size, percentage of children with a migration background, parental involvement in school affairs, classroom insulation, road-traffic and railway noise at school	Reading comprehension – measured using the Suffolk Reading Scale	A 1 dB increase in LAeq is associated with an increase in distraction of .147 scale points. Fully-adjusted multilevel models showed that LAmax and Emergence (separately calculated models) are significant predictors of distraction of children due to aircraft noise (mediator); which in turn has a significant impact on reading performance
Seabi J et al., Expo Sci Environ Epidemiol. 2015	Longitudinal field study	Cohort of 732 learners with a mean age of 11.1 years participated at baseline measurements in 2009 and 650 and 178 learners were reassessed after the relocation of the airport in 2010 and 2011, respectively	Aircraft noise - To measure the external noise surrounding the five schools, a SVAN 955 Type 1 sound lever meter was utilised	54.4–55.3 Leq and 73.2–74.3 Lamax	Gender, deprivation, language spoken at home and groups on reading comprehension in 2010 and 2011	Reading comprehension – measured using the Suffolk Reading Scale	Results revealed no significant effect of the groups on reading comprehension across the testing periods, but significant effects of home language were demonstrated on reading comprehension.
Silva et al., 2016, Applied Acoustics	Cross sectional	The survey covered nine classes located in three primary schools	A sound-level meter of accuracy class 1 was used to measure noise levels	55 dB	No adjustments made	Impact of noise – measured through subjective and objective evaluation	Measurements of indoor and outdoor noise suggest that noise from the outside (road, schoolyard) affects the background noise level in classrooms but in varying degrees
Eagen et al., 2017	Cross-sectional observational field study	134 1½ hour classroom observation sessions of 2nd, 3rd, 4th and 5th Grade children attending schools near Los Angeles airport (LAX)	11 schools from 2 school districts: one school district subject to noise primarily from arrivals operations at LAX. Other school district not heavily influenced by LAX operations.	Short-term LAeq 1s, 5s, 10s, 30s; TA (time above) 55dB, 60dB and 65dB; and NA (number above) 55dB, 60dB and 65dB.	School level assessment of free school meals, ethnicity, English Language Learners.	Student distracted or interrupted by a noise source (observed). Also observed teaching voice raising and voice masking behaviour.	Short-term exposure to aircraft noise events and teacher voice masking and voice raising behaviour but no effect on student distraction