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Systematic Review

Urban noise and psychological distress: a systematic review

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Abstract: Chronic exposure to urban noise is harmful both for auditory perception, with perceptive hearing loss, and for other human systems, in particular cardiovascular, gastrointestinal, psychic nervous and for annoyance. Around 25% of the EU population experience a deterioration in quality of life due to annoyance and about 5-15% suffer from sleep disorders, with more DALYs lost annually. This systematic review highlights main sources of urban noise, principal clinical disorders and more involved countries. Research included articles published on the major databases (PubMed, Cochrane Library, Scopus), using a combination of some keywords. The online search indicated 265 references; after selection, authors have been analyzed 54 articles (5 reviews and 49 original articles). From our analysis, among the sources of exposure, we found more items on airports and wind turbines, followed by roads and train; while, the main disorders investigated in the population relate to annoyance and sleep disorders, followed by cardiovascular risks. About countries, studies come from all over the world with a slight prevalence of Western Europe. Considering these fundamental health consequences, research needs to be amplified, including new sources of noise and new technologies, to ensure a health promotion system and reduce the risk of residents being exposed.

Keywords: urban noise, environmental, annoyance, sleep disorders, health disorders, residents, exposure, dose-response

1. Introduction

Noise pollution is defined as "noise in the living environment or in the external environment such as to cause discomfort or disturbance to rest and human activities, danger to health, deterioration of ecosystems, material goods, monuments, the external environment or such as to interfere with use of the rooms themselves” [1].

This type of pollution can mainly result from vehicle traffic, railways, airports, constructions, industries, recreational activities, etc [2].

Recent statistics estimate that environmental noise was responsible for at least one million healthy life years lost per year in Western Europe [3]. Moreover, as many as 125 million European citizens are exposed to noise levels derived from road traffic above average annual levels of 55 dB, but these figures could actually be significantly higher. Such an exposure involves the perception of annoyance

for 20 million inhabitants, for 8 million the appearance of sleep disorders and it's responsible for more than 40.000 hospitalizations. In addition, around 8000 children in Europe are believed to have difficulty reading and concentrating in areas where air traffic noise is close to school buildings [4].
Prolonged exposure to noise can be harmful to auditory perception, with the onset of perceptual hearing loss, and to other human systems, in particular cardiovascular, gastro enteric, nervous-psychic and annoyance. Epidemiological studies have shown that exposure to residential road traffic noise can lead to the development of cardiovascular disease and stroke [5], metabolic disease [6] and possibly breast cancer [7,8]. Also, exposure to residential road traffic noise may increase the risk of weight gain [9], obesity [10,11] and type II diabetes mellitus [12].
Data on the possible development of oncological pathologies are still controversial; a Danish study on long-term exposure to residential road and railway noise about breast cancer, in a Danish Diet, Cancer and Health cohort, detected a positive association between these exposures and Estrogen Receptors-negative cancer [13]. A study on Breast Cancer survival in the same cohort found no association between residential road traffic noise and concurrent breast-cancer-specific mortality [7]. Finally, a case-control study of women living close to Frankfurt airport found no association between traffic or railway noise and cancer overall but found a positive association between aircraft noise and Estrogen Receptors-negative type [8].
It has been estimated that around 25% of the EU population experience a deterioration in quality of life due to annoyance and about 5-15% suffer from sleep disorders [14]. According to WHO, more than 1 million healthy life years (DALYs) are lost annually because of environmental noise exposure in European member states alone; most of these can be attributed to noise-induced sleep disturbance and annoyance [3].
For this, the EU has issued some directives; the 2002/49/CE Directive has the primary objective of avoiding, preventing or reducing the harmful effects of exposure to environmental noise, by determining the exposure to noise (by means of acoustic mapping), public information on noise 'effects and the adoption of action plans [15]. Also, Legislative Decree 194/2005 implements the previous directive on the determination and management of environmental noise; it defines the procedures of competences for the installation of strategic noise maps in urban areas with more than 100.000 inhabitants, guaranteeing public participation [16].
This systematic review is intended to report scientific articles from the past 10 years concerning the exposure to urban noise, identifying the sources that cause more discomfort in citizens, the major pathologies associated with them and countries most involved.

2. Materials and Methods

This systematic review follows the Prisma Statement [17].

LITERATURE RESEARCH

The research included articles published in the last 10 years, from 2010 to 29 February 2020, on the major online databases (Pubmed, Cochrane Library and Scopus). The search strategy used a combination of controlled vocabulary and free text terms based on the following keywords: noise, annoyance, exposure, dose-response. All research fields were considered. Additionally, we practiced a hand search on reference lists of the selected articles and reviews to carry out a wider analysis.

Two independent reviewers read titles and abstracts of the reports identified by the search strategy. They selected relevant reports according to inclusion and exclusion criteria. Doubts or disagreements were solved by discussion with a third researcher. Subsequently, they independently screened the corresponding full text to decide on final eligibility. Finally, the authors eliminated duplicate studies and articles without full texts.

ELIGIBILITY AND INCLUSION CRITERIA

The studies included in this review focus on urban noise and residents exposed to this risk. We have included articles on exposure to major sources of urban noise such as airports, railways, roads and wind turbines. We included study on principal disease to this exposure, in particular psychological distress and annoyance. No restrictions were applied for language. Articles describing the results of primary studies, systematic or narrative reviews were included.

EXCLUSION CRITERIA

We have excluded reports related only occupational exposure, publications on programmatic interventions and studies without noise' diseases. We have also excluded reports of less academic significance, editorial articles, individual contributions, and purely descriptive studies published in scientific conferences without any quantitative and qualitative inferences.

QUALITY ASSESSMENT

Three different reviewers assessed the methodological quality of the selected studies with specific rating tools. We used International Narrative Systematic Assessment (INSA) method to judge the quality of narrative reviews [18], Assessment of multiple systematic reviews (AMSTAR) to evaluate systematic reviews [19] and the Newcastle Ottawa Scale (NOS) to evaluate cross-sectional, cohort studies and case control studies [20]; while the Jadad Scale was applied for randomized clinical trials [21].

3. Results

The online research indicated 265 references: PubMed (60), Scopus (186) e Cochrane Library (19). Of these, 128 were excluded because not related to the urban noise. Of the remaining, 40 articles were excluded because duplicates.

Finally, 54 studies were included in this systematic review [Fig.1]. Of these, 2 are systematic reviews, 3 are narrative reviews and 49 are original articles. Among original articles, 41 are cross-sectional studies, 3 cohort studies, 3 case-control studies and 2 trials [Tab.1].

Germany is the country in which more studies have been published, among those included in the review (10 articles; 18.5%); most of the articles were published in 2017 (10 studies; 18.5%), followed by 2016 and 2019 (9 and 8 articles, respectly; 16.6% and 14.8%). The selected articles mainly investigate the psychological distress' symptoms shown by residents, such as annoyance (28 studies; 51.8%), sleep disorders (11 articles; 20.3%) or both (11 articles; 20.3%).

Taking into account the studies that examine a single source of noise, airport noise is the prevalent examined exposure (15 articles; 27.7%), followed by traffic roads, wind turbines and railways (10, 8 and 4 studies; 18.5%, 14.8% and 7.4%, respectly).

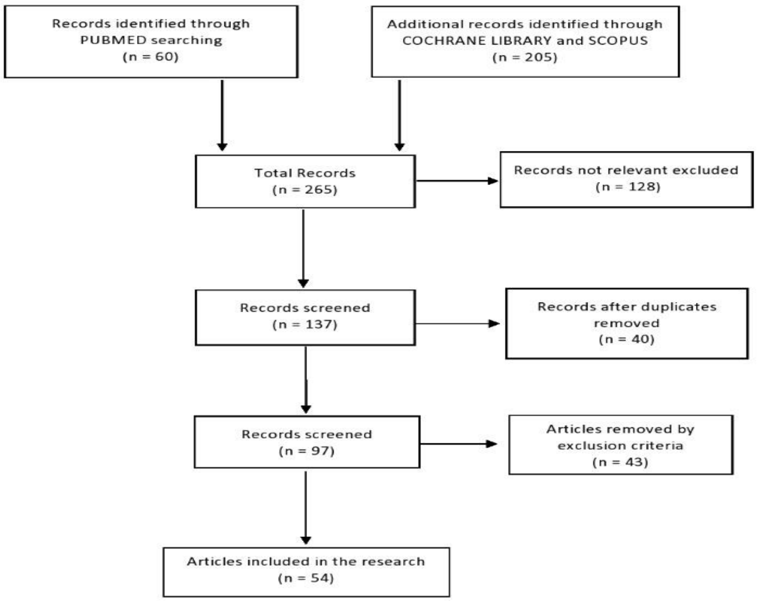

Figure 1- Flow chart of the systematic review

First Author	Year	Study	Country	Noise Exposure	Disease
Ancona	2014	cross sectional	Italy	airport	sleep disturbance, annoyance, cardiovascular
Bakker	2012	cross sectional	Netherlands	wind turbine	annoyance, sleep disturbance
Baudin	2018	cross sectional	France	airport	annoyance and psychological health
Brink	2019	cross sectional	Switzerland	road, rail, airport	sleep disturbance
Brink	2019	cross sectional	Switzerland	road, rail, airport	annoyance
Brown	2015	cross sectional	China	road traffic	sleep disturbance
Bunnakrid	2017	cross sectional	Thailand	road traffic	annoyance
Camusso	2016	cross sectional	Italy	road traffic	annoyance
Elmehdi	2012	cross sectional	Emirates	airport	annoyance
Elmenhorst	2019	trial	Germany	road, rail, airport	sleep disturbance
Erikson	2017	cross sectional	Sweden	road, rail	sleep disturbance, annoyance, cardiovascular
Fryd	2016	cross sectional	Denmark	road traffic	annoyance
Gjestland	2017	cross sectional	Norway	airport	annoyance
Gjestland	2015	cross sectional	Vietnam	airport, road	annoyance
Gjestland	2019	cross sectional	Norway	airport, road	annoyance
Guski	2017	systematic review	Germany	airport, road, railway	annoyance
Hays	2016	narrative review	USA	oil gas development	sleep disturbance, annoyance, cardiovascular
Hong	2010	cross sectional	Korea	road, rail	sleep disturbance
Hongisto	2017	cross sectional	Finland	wind turbine	annoyance
Hume	2010	narrative review	Uk	airport	sleep disturbance
Janssen	2011	cross sectional	Sweden, Netherlands	wind turbine	annoyance
Kageyama	2016	case control	Japan	wind turbine	sleep disturbance
Kim	2014	case control	Korea	airport	sleep disturbance
Kim	2012	cross sectional	USA	road traffic	annoyance, sleep disturbance
Lercher	2013	cross sectional	Austria	road traffic	annoyance
Lechner	2019	cross sectional	Austria	road, rail, airport	annoyance
Lercher	2011	narrative review	Austria	road, rail	cardiovascular
Lercher	2017	cross sectional	Austria	road, rail	annoyance
Lercher	2012	cross sectional	Austria	road, rail, airport	annoyance, sleep disturbance
Lercher	2010	cross sectional	Austria	rail	sleep disturbance
Liu	2017	cross sectional	China	construction	annoyance
Magari	2014	cross sectional	USA	wind turbine	sleep disturbance
Matsui	2013	cross sectional	Japan	airport	psychological distress
Miller	2015	cross sectional	USA	airport	annoyance
Morinaga	2016	cross sectional	Japan	airport	annoyance
Muller	2016	cohort study	Germany	airport	sleep disturbance
Ogren	2017	cross sectional	Sweden	rail	annoyance
Pedersen	2015	cross sectional	Sweden	road traffic	annoyance
Pennig	2014	cross sectional	Germany	rail	annoyance
Poulsen	2019	cohort study	Denmark	wind turbine	sleep disturbance
Ragettli	2015	cross sectional	Canada	road, rail, airport	annoyance
Schmidt	2015	trial	Germany	airport	cardiovascular
Schmidt	2014	systematic review	Denmark	wind turbine	annoyance, sleep disturbance
Schreckenberg	2013	cross sectional	Germany	rail	annoyance
Schreckenberg	2016	cohort study	Germany	airport	annoyance, sleep disturbance
Schreckenberg	2010	cross sectional	Germany	airport	annoyance
Shepherd	2013	cross sectional	New Zealand	wind turbine, airport	annoyance
Shimoyama	2014	cross sectional	Japan	road traffic	annoyance, sleep disturbance
Silva	2016	cross sectional	Brazil	airport	annoyance
Tainio	2015	cross sectional	Poland	road traffic	annoyance
Tobollik	2019	cross sectional	Germany	road, rail, airport	sleep disturbance, annoyance, cardiovascular
Trieu	2019	cross sectional	Japan	airport	sleep disturbance, annoyance, cardiovascular
Wothge	2017	cross sectional	Germany	road,rail,airport	annoyance
Yano	2013	cross sectional	Japan	wind turbine	annoyance

Table 1- All included studies in this systematic review, in alphabetical order

3.1 Narrative and systematic reviews

As regards the methodological quality of the selected reviews, the AMSTAR score shows an average of 7, thus indicating a discrete quality of the studies (Tab.2). The most appropriate methodological systematic review was conducted in Germany by WHO (AMSTAR = 8). As regards narrative reviews scores, the INSA score shows an average 5.6, a median and a modal value of 6, indicating an intermediate quality.

First Author	Included Articles	Principal results	Score
Guski	62	The evidence of exposure-response relations between noise levels and %HA is moderate (aircraft,railway) or low (road traffic, wind turbines). The evidence of correlations between noise levels and annoyance raw scores is high (aircraft,railway) or moderate (road .traffic,wind turbines)	A.8
Hays	*narrative*	Oil and gas activities produce noiseat levels that may increase the risk of adverse health outcomes, including annoyance, sleep disturbance, and cardiovascular diseases.	I.5
Hume	*narrative*	Annoyance is the mediating factor between noise exposure and cardiovascular diseases with annoyance has associations with a number of cofactors like noise sensitivity, negative affectivity and mental health.	I.6
Lercher	*narrative*	Important modifiers may partly be responsible for the large variations found in the noise health effects (socio-demographic factors, lenght of exposure, bedroom).	I.6
Schmidt	36	A dose-response relationship between wind turbine noise linked to noise annoyance, sleep disturbance and possibly even psychological distress is present in the literature.	A.6

Table 2- Included review with their relative score

Each review addresses a different topic, both for the source of noise and the pathology investigated. In ones, annoyance and sleep disturbance are all related to increasing sound pressure levels of wind turbines more than other sound sources, especially in rural areas; annoyance has in general been reported to be between 10–45% of the population if the sound exposure was above 40 dB(A) but less than 10% if the sound exposure is below 35 dB(A). Sleep disturbance is only seen at high exposure levels above 45 dB and this problem is significantly related to annoyance [22]. Also, Hume highlights that this alteration appears from 30-40 dB at night airport ʻexposure and new technologies will play an ever greater and more important role; for example, the "open rotor engine," may achieve development in 10-20 years and is projected to give significantly more fuel efficient, less carbon dioxide per air mile, but more noise [23].

Instead, Hays reviewed the scientific literature on oil and gas development activities. This economic sector issues low frequency noise (for example, by compressor stations) but, however, there are few data available about his consequences, such as cardiovascular risks or adverse birth outcomes; most of these activities are not permanent in technological areas, so there may be fewer studies on long-term effects [24]. Potential cardiovascular risk has also investigated by Lercher, in Alpine Region; he focused on two studies (the Noise Village Study and the Transit Study), in which however it does not emerge a relevant relationship between traffic noise and systolic blood pressure. The authors have highlighted a possible linear relationship with systolic pressure, only in men, over 60 years and exposure ʻsound between 50 and 60 dBA Lden (OR = 1.38, CI = 1.03-1.86) [25].

Finally, Guski has described the association between exposure to various environmental noise and annoyance; the exposure-response relations between noise levels and highly annoyed is moderate for aircraft and railway or low for road traffic and wind turbines. Highly annoyed people are not only elevated at" high-rate change" airports (Frankfurt, Berlin-Brandenburg), but also near" low-rate change" airports (Cologne/Bonn, Stuttgart) [26].

3.2 Original Articles

The scores assigned to the original articles have an average value of 6.2, a median 6 and a modal of 6 (Tab. 3). This situation amounts to an intermediate quality of the studies; Switzerland, Netherland, France, Sweden and Austria obtained the highest values (NEW CASTLE = 8).

First Author	Included subjects	Noise'source	Exposure Range	Questionnaire	Results	Scores
Ancona	N.896322	airport	Lden 55-70 dB	not used	above 55 dB there were 4607 cases of hypertension,3.4 cases of AMI, 9789 cases of annoyance, 5084 sleep disorders	N.6
Bakker	N.725	wind turbine	21-54 dB	GHQ	a dose-response relationship was found between wind turbine sound and annoyance	N.8
Baudin	N.1244	airport	<45->60 dB	GHQ	22% of the participants were considered to have psychological ill-health;annoyance due to aircraft noise and noise sensitivity were both significantly associated with psychological ill-health	N.8
Brink	N.5592	road, rail, airport	20-80 dB	ICBEN 5-point scale	bedroom orientation shows strong effect with sleep disorders	N.8
Brink	N.5592	road, rail, airport	Lden 30-85 dB	ICBEN 11-point scale.	Aircraft noise annoyance scored markedly higher than annoyance to railway and road traffic noise at the same Lden level. Railway noise elicited higher percentages of highly annoyed persons than road traffic noise.	N.8
Brown	N.10077	road traffic	Lden 42-78 dB	not all specified, Weinstein scale	population in Hong Kong exposed to high levels of road traffic noise (>70 dB) is similar to that found in cities in Europe. However, a much higher proportion of the population in Hong Kong compared to European cities is exposed to Lden levels of road traffic noise of 60–64 dB, and a much lower proportion to the lower levels (<55 dB).	N.7
Bunnakrid	N.253	road traffic	Leq 69.3-75.4	ICBEN 5-point scale	Average annoyance scores of traffic noise in Muang Phuket, Thalang, and Kathu were 1.78, 2.52, and 2.75;a significant positive correlation between road traffic noise and annoyance level (P=0.025)	N.6
Camusso	N.830	road traffic	Leq 35-105 dB	ICBEN 5,7 point-scale	people are more annoyed in broad street than narrow street; dose-response curve shows a higher sensitivity in people living in broad stree	N.7
Elmehdi	N.23	airport	Ldn 40-80	ISO/TS 15666-2003 questionnaire	41% of the respondents near Dubai airport are highly annoyed	N.6
Erikson	N.971839	road, rail	not specified	not used	DALY attributed to traffic noise in Sweden was estimated to be 36 711 (90%) related to road traffic and 4322 (10%) related to railway traffic, specially sleep disorders, 22 218 DALY (54%), followed by annoyance, 12 090 DALY (30%) and cardiovascular diseases, 6725 DALY (16%).	N.8
Fryd	N.6761	road traffic	48-75 dB	ISO/TS 15666-2003 questionnaire	Outdoor annoyance was higher for motorways than urban roads while the indoor annoyance was the same	N.7
Gjestland	N.32	airport	<40 - > 80 dB	not specified	At so-called LRC airports ighly annoyed residents increases with an increasing amount of traffic. The same tendency cannot be found for HRC airports. At this type of airports the annoyance assessment is therefore most likely dominated by other non-acoustical factors	N.6
Gjestland	N.104	airport, road	not specified	not used	The CTL method for characterizing the annoyance caused by long term exposure to noise is a robust method that segregates acoustical from non-acoustical influences on annoyance prevalence rates	N.7
Gjestland	N.7199	airport, road	<40 - > 80 dB	ICBEN 5-point scale.	CTL was 73 dB for aircraft noise and 84 dB for road noise	N.7
Hong	N.1160	rail, road	Laeq 49-74 dB	CENVR	sleep is affected more by railway noise than by road traffic noise; sensitivity was shown to be a significant modifying factor	N.7
Hongisto	N.429	wind turbine	Laeq 26.7–44.2 dB	ISO/TS 15666-2003 questionnaire	indoor noise annoyance was correlated with sound level and distance (p=2.4x10; p=8.5x10)	N.7
Janssen	N.351, 754, 725	wind turbine	25-60 dB	ICBEN 5 point-scale	annoyance due to wind turbine noise is found at low exposure level; percentage of annoyance by wind turbine noise is expected at much lower levels of Lden than the same percentage of annoyance by for instance road traffic noise	N.7
Kim	N. 109,967	road traffic	<40 - > 80 dB	not specified	Many residents of the greater Atlanta area may be exposed to noise levels that put them at risk of being highly annoyed or having high levels of sleep disturbanc	N.6
Lercher	N. 2002/1643	road traffic	<40 - > 80 dB	not specified	In Alpine valley, accumulation of factors can in some cases lead to higher annoyance from main roads than from highways	N.7
Lechner	N.1031	road, rail, airport	<45 - >55 dB	ICBEN 11-point scale, EU-SILC 2015,	all tra/fc noise sources positively and significantly increased the overal annoyace score	N.8
Lercher	N.1641	road, rail	<40 - > 80 dB	ICBEN 5 point-scale	Distance to highway and railway track is negatively associated with annoyance (p < 0.001) while distance to the main road slightly failed significance (p = 0.071), sleep disturbance and coping scores are positively associated with higher annoyance (p < 0.001). Longer duration of living in the home is not significantly associated with higher annoyance (p = 0.163)	N.6
Lercher	not specified	road, rail, airport	<40 - > 80 dB	ICBEN 11-point scale	A linear dose response relation was found between number of events >69 dBA and % rather and very annoyed.	N.6
Lercher	N.1643	rail	40- 75 dB	5-point Likert-type, PCL-C	more than twice the probabilities of medication intake at any level of railway sound exposure, in particular between 65-75 dB	N.7
Liu	N.1027	construction	Laeq 15.30-77 dB	ICBEN 7,11 point-scale	when Laeq of construction noise increases from 60 dB to 80 dB, highly annoyed increase from 15% to 40%	N.6
Magari	N.62	wind turbine	not specified	Pedersen 2004	no statistically significant associations between sound level measurements inside or outside, and an individual's assessment of their satisfaction with living environment and annoyance with the turbines at the P < 0.05 level	N.7
Matsui	N.3215	airport	Lden 55-70 dB	Total Health Index	the PSD score showed significant association with sleep disturbance, although the annoyance score showed higher association with speech interference than sleep disturbance.	N.6
Miller	N.366	airport	not specified	Not validated	who believe the airport is very important are less likely to be annoyed by the noise.	N.5
Morinaga	N.4298	airport	Lden 31-80 dB	ICBEN 5 point-scale	Lden value for military aircraft noise is 5-7 dB higher than civilian at an equal rate annoyance response	N.6
Ogren	N.1203	rail	40.8- 64.9 dB	ISO/TS 15666:2003	annoyance from noise may be influenced by the presence of vibration (p 0.022)	N.6
Pedersen	N.385	road traffic	not specified	GHQ	The highest frequencies of annoyance were found for vibration from buses or trucks (23%), noise from passing cars (22%), noise from mopeds and motorbikes (20%), motorway noise (17%)	N.6
Pennig	N.380	rail	40-89.9 dB	ICBEN 11-point scale.	64.3% are highly annoyed by trains and 20.7% by roads, especially during night	N.6
Ragettli	N.4336	road,rail,airport	50.1–76.1 for LAeq24h	European LARES-survey	annoyed by road traffic, airplane and train noise was 20.1%, 13.0% and 6.1%, respectively	N.6
Schreckenberg	N.1211	rail	<40-85 dB	ICBEN 5 point-scale	%HA and %HSD due to railway noise increases with increasing railway noise levels. For equivalent sound levels above 65 dB %HA for railway noise railway at daytime against L day is somewhat higher than %HA at night and considerably higher than %HSD against Lnight	N.6
Schreckenberg	N.2312	airport	<40 - >60 dB	Not validated	aircraft noise annoyance is associated with sound levels as well as with the number of flyovers (N55, N70). However, the strongest exposure-annoyance relationship for aircraft noise was found between the equivalent sound level and aircraft noise annoyance	N.6
Shepherd	N.823	wind turbine, airport	Lden 55-76 dB	WHOQOL-BREF, NOISEQ	The dose-response relationships between noise annoyance and HRQOL measures indicated an inverse relationship;quiet areas were found to have higher mean HRQOL domain scores than noisy areas	N.6
Shimoyama	N.4966	road traffic	Lden 61-83 dB, Laeq 50-73 c	ICBEN 5,11 point-scale	dose-response curve showed that Vietnamese respondents were about 5 to 10 dB less annoyed by road traffic noise than those of EU and Japan	N.5
Silva	N.547	airport	37.5-75 dB	ISO 15666:2003	In range 67.5-70 dB, 68.4% of the sample is highly annoyed (CTL50%= 65.3 dB)	N.6
Tainio	not specified	road traffic	not specified	not used	58000 DALYs in Poland, 44% due to air pollution and 46% due to noise	N.6
Tobollik	not specified	road, rail, airport	not specified	not used	Highest burden was found for road traffic noise in Germany, with 75896 DALYs	N.7
Trieu	N.755	airport	Lden 38-76 dB	not validated	no significant association between hypertension and noise exposure but a a significant relationship between insomnia and nocturnal noise exposure	N.6
Wothge	N.4905	road,rail,airport	40-60 dB	ICBEN 5-point verbal scale	annoyance grows significantly with the increase of the Laeq,24h of the aicraft noise and in combination of noise sources (airport+rail/roads)	N.7
Yano	N.747	wind turbine	26-50 dB	ICBEN 5-point verbal scale	When LAeq,n increased from 26 to 50 dB, annoyed gradually increased from 3 to 21, from 6 to 27 and from 25 to 48%,respectively.Annoyance'rate depends by home'location, temperature and wave sound	N.6

Table 3- Included cross articles, in alphabetical order, with their relative scores

In order to carry out the results and considered the quantity of the selected articles, we proceed with a synthesis of the results based on the urban noise 'sources and main disorders found by the authors.

3.2.1 Noise' sources

There are four main sources of exposures investigated by the authors; 13 articles (13/47; 27.6%) investigate only noise from airport sources, 7 from damage caused by wind turbines (7/47; 14.8%), 9 from road or motorway traffic (9/47; 19.1%) and 4 from rail traffic (4/47; 8.5%).

In 13/47 articles (27.6%), multiple sources are involved, particularly in 7 studies of airport-train-road (7/13; 53.8%), 3 road-rail (3/13; 23%), 2 (2/13; 15.3%) airport-road and one (1/13; 7.6%) wind turbine - airport.

We have found that type of airport can interfere with the symptoms reported by the population.

For example, Morinaga found that living near military airports has worse consequences than civilians. In fact, comparing his data with a survey on civil airports, the author notices that more decibel are needed to obtain the same values of highly annoyed [27]. The percentage of insomnia and sleep disorders vary with the increase of night flight operation [28]. Also, Mueller found that awakeness'average decreased from 2 in 2011 to 0.8 in 2012 because there are less night flights [29]. Schreckenberg, in 2016, has shown how levels of annoyance and sleep disorders have fallen after some interventions in the airport, except with respect to disturbance upon awakening in the early morning [30].

There was a correlation between "value at which half of the people in a community describe themselves as highly annoyed by noise exposure" (CTL) and number of aircraft movements. In fact, near HRC airports (high rate of change), authors found more annoyed people. Gjestland has highlighted that 20% of Highly Annoyed find around 55 dB (at the same value, near "low rate of change" airport, annoyed are 5%) [31]; at same, Silva has showed that the air traffic at Guarulhos airport increased about 45% on the last 5 years before the survey, as well as the percentage of annoyed citizens [32] .

The location of the house also affects annoyance. This symptom at sites with sea wave sound was significantly lower than that at sites without, probably because of masking by sea wave sound [33]. In Schkeckember study, residents with predominantly closed windows in the bedroom are higher sleep disturbed by railway noise than residents with predominantly open or half-open windows ($p <0.001$), $p <0.033$ respectly), independently of the type of windows (sound proof windows, single-/double-glazed windows) and of the funding of sound proof windows [34]. In the case of road noise, the association between LNight and these disturbances depended on the orientation of the bedroom towards the nearest street; in fact, with a bedroom pointed away from the nearest street, the less sleep-disturbed respondents were [35]. Strong relationship between the distance to the noise source and the prevalence of annoyance from all transportation noise sources, the percentage of highly annoyed due to road traffic noise was 22% within 50 m, 10% within 51–100 m, and below 10% at categories of 100 and more meters away from major roads. The rates due to noise from trains rapidly decreased when moving away from the railway tracks [36]. Also, distance from wind turbine The indoor noise annoyance was systematically reduced with increasing distance. In Hongisto'data, the rate of annoyed was under 10% already in the distance category 800–1200 m and reached almost zero in the distance category 1600–2000 m [37].

Annoyance and sleep are also influenced by other factors. In Schkemberg study, the individual noise sensitivity is correlated with aircraft noise annoyance ($r = 0.36$) but as expected not with the aircraft sound level. Age was found to be non-linear related to aircraft noise annoyance, that is annoyance due to aircraft noise was higher in the group of middle-aged adults (40–60 years) in comparison to younger or older ($p < 0.001$); residents with a lower socio-economic status reported less annoyance due to aircraft noise than middle-higher socio-economic status ($p < 0.001$). House owners more annoyed by aircraft noise than tenants ($p < 0.001$); the fear of diminished house prices is correlated with aircraft noise annoyance ($r = 0.54$, $p < 0.001$) and with aircraft sound level Lden ($r = 0.17$, $p < 0.001$) [38]. Pedersen found that respondents if stimulated by only one stressor were most often annoyed by noise (51%) or odor (27%). By different stressors, 32% were sensitive to noise, 43% to odor, and 32% to vibration [39]. Sensitivity was shown to be a significant modifying factor ($p = 0$ in railway and roads) and gender for railway ($p=0.014$), as it pertains to subjective sleep disturbance [40]. In addition, in Brown'paper, the odds ratios show that respondents in medium and high Noise Sensitivity categories were 1.5 and 2.4 times more likely to be Highly Annoyed than were respondents in the low Noise Sensitivity category. Respondents who were dissatisfied overall with their residential area were 3.5 times more likely to be Highly Annoyed than respondents not dissatisfied with their area [41]. Ogren compares vibration exposure to noise exposure from railway traffic in terms of equal annoyance; the noise levels and vibration velocities that had an equal probability of causing annoyance was determined using logistic regression. For equivalent noise level at the facade compared to maximum weighted vibration velocity in the ground the probability of annoyance is approximately 20% for 59 dB or 0.48 mm/s, and about 40% for 63 dB or 0.98 mm/s. The author found that annoyance from noise may be influenced by the presence of vibration ($p = 0.022$), but annoyance from vibration is perhaps not influenced as much by the noise level ($p = 0.72$) [42]. Brink, in 2019, hypothesized that highly intermittent noise has more potential to disturb certain activities. This was confirmed by higher annoyed in highly intermittent rail and aircraft noise, but they found that IR24h (intermittency ratio measured over 24h) has the opposite effect on road traffic noise annoyance: for road traffic noise, exposure with low IR24h (most certainly motorways) were associated with "highly annoyed" responses that were > 6 dB higher than situations with high IR24h [43].

3.2.2 Main disorders

Of our 47 original articles, 28 exclusively investigate annoyance (28/47; 59.5%). In other cases, 9 publications focus their findings on sleep disorders (9/47; 19.1%); as many as 9 articles investigate both disorders, both the psychological health, annoyance and sleep disorders. Finally, in 4 cases (4/47; 8.5%), in addition to the psychological sphere, cardiovascular disorders due to urban noise are reported. Of the 28 exclusive annoyance 'studies, 6 correlate this disorder with both airport and road noise (6/28; 21.4% respectively). On the other hand, among the 9 exclusive studies on sleep disorders, 3 correlate to wind turbines, 2 aircraft, 1 road, 1 rail, 1 road-rail and 1 airport-rail-road.

Ancona estimated that levels higher than 55 dB cause more than 4000 cases of hypertension and more than 9000 of annoyance; in the areas where night levels reach 50 dB, there were over 5000-sleep disorders 'events [44]. In Poland, health burden due to noise was caused by the annoyance (49%), sleep disturbance (38%) and ischemic heart diseases (13%); for the noise burden the uncertainties were large so that for the annoyance the mean DALY was 12.000 and the 95% ranged from 4000 to 27.000 [45]. The most important contributor to the Sweden disease burden was sleep disturbances, accounting for 22218 DALY (54%), followed by annoyance with 12090 DALY (30%) and cardiovascular diseases with 6725 DALY (16%) [46]. In Germany, the highest burden was found for road traffic noise, with 75.896 DALYs. When including all available evidence, 176.888 DALYs can be attributable to road traffic noise; comparing the burden by health outcomes, the biggest share is due to ischemic heart disease (90%) about aircraft noise [47].

For Kim, the prevalence of sleep disturbance was high in the order of noise level ($p < 0.001$). The mean scores of the PSQI subscale were high, increasing with the level of noise, except in the case of sleep latency and use of sleeping drugs [48]. In Poulsen'study, five-year mean outdoor nighttime of ≥42 dB was associated with a hazard ratio HR=1.14 (CI: 0.98-1.33) for sleep medication and HR=1.17 (CI: 1.01-1.35) for antidepressants. The association was strongest among people ≥65 years of age, with HRs=1.68 (1.27-2.21) for sleep medication and 1.23 (0.90-1.69) for antidepressants [49]. In addition, Lercher has investigated the relationship between railway noise and sleep medication intake; he shows more than twice the probabilities of medication intake at any level of railway sound exposure and a non-linear exposure-response curve, with a statistically significant leveling off around 60 dB [50]. Insomnia was significantly prevalent among those who were interested in environmental problems, those who felt visually annoyed with the wind turbines and those who reported themselves sensitive to noise, compared with in the rest of the respondents [51]. Sleep disturbance increased with increasing sound pressure level, especially at levels over 45 dB (A) where 48% of the respondents reported sleep disturbance. This correlation is significant in quiet areas ($r=0.208$, $p<0.05$) and in all (quiet and noisy) area types ($r=0.160$, $p<0.01$) [52].

Most annoyed had lower mean domain for all HRQOL domains than not annoyed, in particular physical ($p < 0.001$), psychological ($p < 0.001$), social ($p < 0.001$) and environmental ($p < 0.001$) [53]. Noise sensitivity and annoyance due to aircraft noise were also significantly associated with psychological ill-health; in fact the authors have observed a gradient between annoyance due to aircraft noise and psychological ill-health, with an ORs 1.79 (CI 1.06–3.03) for people who were not all annoyed and an ORs 4.00 (CI 1.67–9.55) for extremely annoyed people [54].

The levels of the construction noise to be higher than the traffic noise. This problem affects activities such as studying/mental activities and sleeping more than watching TV/listening to music and conversation, with house working the least, principally in daytime ($p < 0.05$) [55]. Exposure-response relationships for awaking, falling asleep, conversation, telephone- listening, TV/Radio listening, reading/thinking, and rest disturbances was found also in Shimoyama'study [56].

Some authors found that more than half of the respondents felt particularly annoyed in the late evening hours (20-23h). Also, at 60 dB (A) the model predicts 14% of highly annoyed is at daytime but 36% for the evening and 39% for the nighttime period. Railway noise caused a variety of reactions in exposed residents, like closing windows, or feelings of anger or irritableness or conversation/radio louder [57]. Fryd has found differences between motorways and urban ways. For motorways, 22% is high annoyed and 48% is annoyed, when noise level is Lden 58 dB; instead, for urban roads, 8% is high annoyed and 28% is annoyed. Comparing high annoyed in both of streets, it is clear that 20% exposed to motorways is highly annoyed with 10 dB less than to roads exposed (55-60 dB vs 65-70 dB). There is an important difference in outdoor annoyance (in motorway case, there were more annoyed with less dB) [58].

3.2.3 Countries

In 7 cases, the research involved exposed areas in Germany (7/47; 14.8%), following 6 cases in Japan, 5 in Austria, 4 in Sweden, 3 in the USA, 2 in Italy, Switzerland, China, Netherlands, Denmark, Korea, Norway and 1 case respectively for France, Thailand, Arab, Vietnam, Canada, Poland, New Zealand and Brazil. Among the German studies, four investigated the airports (4/7; 57.1%); also for Japan with three studies (3/6; 50%). Austrian studies 4 focus on trains and roads, particularly in the Alpine region, on the border with the Brenner.

3.3 Trials

We have found only two sperimental studies (2/47; 4.2%) (Tab.4).

First Author	Included subjects	Noise'source	Exposure'range	Questionnaire	Results	Lenght	Score
Elmenhorst	237	rail,road,airport	45-80 dB	Freiburger Persoenlichkeits Inventar	Sound pressure levels increased in the order aircraft < road < railway noise, the awakening probability from road and railway noise being not significantly different (p = 0.988). At 70 dB SPL, it was more than 7% less probable to wake up due to aircraft noise than due to railway.	4-13 nights	J.2
Kageyama	747 cases/332 controls	wind turbine	35-40 dB	THI	Odds ratio of insomnia was significantly higher when the noise exposure level exceeded 40 dB, whereas the self-reported sensitivity to noise and visual annoyance with wind turbines were also independently associated with insomnia.	2010-2012	N.6
Kim	871 cases/134 controls	airport	<60 - >80 WECPNL	PSQI, DASS	Sleep disturbance was 45.5% in the control group, 71.8% in the low exposure group,77.1% in high exposure (p 0.001).	2009-2011	N.6
Mueller	202	airport	not specified	Polysomnography	By reducing nocturnal overflights, awakening decreased from 2.0 per night in 2011 to 0.8 per night in 2012.	2011-2013	N.5
Poulsen	584891	wind turbine	<24 - >42 dB	not specified	WTN of ≥42 dB was associated with a HR=1.14 for sleep medications and 1.17 for antidepressants (compared to < 24dB).	1996-2003	N.6
Schmidt	60	airport	36-49 dB	PSQI	Night-time aircraft noise markedly impairs endothelial function in patients with or at risk for cardiovascular disease.	any nights	J.3
Schreckenberg	9244- 3508	airport	36-61 dB	ICBEN 5-point scale	Exposure response curve for aircraft annoyance after opening new runway depends on local changes in sound level.	2011-2013	N.5

Table 4- Sperimental, case-control, cohort study, with their relative scores

Elmenhorst, comparing three different laboratory experiment about principal noise'effects on sleep, found that different traffic noise sources induce different awakening probabilities. At equal level, the awakening probability due to the three traffic noise sources increased in the order aircraft - road -

railway noise (so, this indicated a higher awakening probability due to railway noise in comparison to aircraft or roads noise). However, the awakening probability from road and railway noise is not significantly different ($p = 0.988$). At 70 dB SPL, it was more than 7% less probable to wake up due to aircraft noise than due to railway noise [59].

In 2015, Schimdt tested the effects of nocturnal aircraft noise on endothelial function in 60 patients, between 30 and 75 years, with either established cardiovascular disease or a 10y cardiovascular risk of at least 10%. Noise was simulated in the patients' bedroom through 60 events during one night. The team recorded patient'polygraphy, endothelial function (by flow mediated dilation of the brachial artery), questionnaires and blood sampling on the morning after each study night and they were compared with not exposed. Sample has an average of 61ys, a mean sound pressure levels of 46.9 ± 2.0 dB(A) in the noise nights and 39.2 ± 3.1 dB(A) in the control nights. They found that sleep quality was markedly reduced by noise from 5.8 ± 2.0 to 3.7 ± 2.2 (p 0.001), flow mediate dilatation significantly reduced (from 9.6 ± 4.3 to 7.9 ± 3.7%; p 0.001) and systolic blood pressure was increased (from 129.5 ± 16.5 to 133.6 ± 17.9 mmHg; $p = 0.030$), by noise. However, the adverse vascular effects of noise were independent from sleep quality and self-reported noise sensitivity [60].

4. Discussion

Noise has negative consequences for the health of exposed individuals, which are widely documented in the scientific literature [61,62,63]. For example, increased blood pressure and cardiovascular disorders are associated with chronic exposure, specially if airport origin [64,65,66,67,68]. On the other hand, among the extra-hearing damage, there is a subjective alteration generally known as "noise disorder" or "annoyance" [69], which arises when a sound source is perceived as annoying, irritating, unwanted, and associated with the presence of symptoms such as irritableness, fatigue, headaches, decreased performance, etc. Noise, such as an environmental stress factor, can be caused an activation of the central and hyperactive nervous system of the sympathetic autonomic nervous system [70], resulting in an increase heart rate, vasoconstriction, increase in blood pressure, changes in blood viscosity, blood lipids and electrolyte alterations [71]. Prolonged exposure to noise can lead, in the most susceptible individuals, to permanent damage, ranging from hypertension to ischemic diseases, to myocardial infarct [72,73] and stroke [74]. Effects such as dysfunctional immune system dysfunction [75], psychic alterations such as irritable, aggressive, and decreased cognitive performance (e.g. difficulty understanding written language) have also been observed in individuals exposed to airport noise [76].

Our review has highlighted some specific risk factors present in this environmental sector, which are deserving of adequate consideration, in particular for the prevention of repercussions on residents' health. As can be expected, most studies agree that the level of annoyance depended on the level of exposure to their sound; a higher exposure increased the chance of being annoyed. In literature, the association between noise exposure and noise annoyance has been extensively investigated, and aircraft noise has been found to be the most annoying noise source among all transportation noise sources when standardized for noise exposure level [77]. Recently, it has been suggested that annoyance due to aircraft noise has increased in previous years [78, 79, 80, 81]. Noise that involves vibrating movements and with spectral content in low frequencies, such as aerial noise, leads to noise reactions that are much more evident than other types of noise, such as tachycardia [82].

Even in our review, the most reported disturbance is annoyance, in relation to airports and road traffic. This disorder is linked to very variable factors: the number of landings and take-offs, the type of aircraft used, the procedures and routes used at these stages and, of course, the characteristics of the territory at the take-off and landing routes, the density of population and human activities. In fact, to protect environmental quality, from an acoustic point of view, a rather complex regulatory system is in place, which includes Community Directives and Regulations, national and regional regulations of implementation, technical standards, involving, in the collegiate body constituted by the Airports Commissions, various subjects: technical-management (ENAC, ENAV, Airport Management Company), institutional (Ministry of the Environment, Region), local authorities (Communities and Provinces), carriers (airline representatives) [83].

With regard to vehicle traffic noise, which has a certain continuity and repetitiveness, it seems that the predominant effect is the disturbance on sleep, in several specific manifestations [73,84]. The WHO suggests that, for a physiologically healthy night rest, outdoor sound events with LAmax greater than 45 dB(A) should be avoided. In addition, the background noise level 1 m from the exterior facade of the bedroom should not exceed 45 dB(A) to allow you to keep the windows open at night [85]. De Kluizenaar et al. found that long-term traffic noise exposure is associated with an increased risk of getting up tired and not rested in the morning in the general population [86]. Nighttime noise turned out to have adverse effects on sleep. Motility, motility onset and heart rate (monitored with ECG-equipment) increased with increasing road and railway noise exposure indoors during sleep. Griefahn and Spreng found similar effects [87]. A large Norwegian study on the impact of road traffic sound found significant relationships between noise annoyance and sleeping problems and strong links between pseudo neurological complaints (palpitation, heat flushes, dizziness, anxiety and depression), annoyance and sleep [88]. Noise induced disturbances vary according to the physical characteristics of the noise events [89]. Dose–response relationships between night sound levels of aircraft noise and effects on sleep could be substantially improved by adding the number of noise events [90]. Saremi et al. found that railway noise disturbs both the macro- and microstructure of sleep and indicated that for the same maximum level and the same patterns during the night, sleep would be more fragmented by freight trains than by passenger and automotive trains [91].

An association between noise annoyance and sleep disturbance was found among residents highly exposed to aircraft noise, but not among those that were exposed at lower levels [92]. Airport noise interferes with the quality of sleep of people living near airports [93,94,95], as shown by some studies in which airport noise has been associated with an increase in the frequency of use of sleeping pills and tranquilizers [96,97,98,99].

In addition, noise is a psychosocial stressor that activates the sympathetic and endocrine systems [100]. As some studies have shown that endocrine distress can lead to psychological symptoms such as depression or anxiety [101, 102, 103]. Studies that research the relationship between annoyance and psychological health start from far away; annoyance due to aircraft noise has been found to be related to psychological distress as measured with the General Health Questionnaire (GHQ) in a study among residents living near Heathrow airport [104]. However, the results are controversial. Some studies, investigating the effects of aircraft noise exposure in dB on mental health, did not find any significant association between aircraft noise exposure and psychological ill-health based on the GHQ-30 [105], the GHQ-28 [106], or the GHQ-12 [107]. Only Miyakawa et al in Japan showed a significant correlation between aircraft noise exposure and moderate/severe somatic symptoms identified by the GHQ-28 in people sensitive to noise [106]. In Spain, outside noise reported as a perceived environmental problem was significantly associated with the prevalence of common mental disorders using the GHQ-12 [108]. Finally, in the United Kingdom, high noise sensitivity was identified by Stansfeld et al. [109] as a predictor of psychological distress using the GHQ-30. Extremely annoyed people might be more at risk of having psychological ill-health, but it is also possible that people with psychological ill-health might be more at risk of being annoyed and then be more willing to attribute their symptoms to noise [110,111].

Annoyance also depends on psychological factors, which are found in our review. For example, noise sensitivity, distance to the source, availability of a quiet side, and window opening behavior, habitual bedroom window position, orientation of bedroom towards the nearest street, sound level difference between minimum and maximum façade point exposure, degree of urbanization, sleep timing (bedtime and sleep duration), sleep medication intake, survey season (winter, spring, summer, autumn), and night air temperature. Noise sensitivity is considered as a moderating factor of the effects of aircraft noise exposure on noise annoyance [112,113, 114, 115]. It has been suggested that noise sensitivity could also influence the effects of noise on physical and psychological ill-health [116]. Noise sensitivity has been suggested to be a potential indicator of vulnerability to environmental stressors, not only to environmental noise [117,118], it has also been postulated to be a proxy measure of anxiety [109]. When positioned in residential areas wind turbines may cause noise annoyance as reported in international literature [119;120,121]. The visual impact of wind turbines has been previously shown to be more pronounced in rural areas when compared to more densely populated areas [122]. Among respondents that benefited economically from wind turbines the proportion of people who were rather or very annoyed was significantly lower, as if wind turbine sound was differently valued by them compared to non-benefiting respondents [123, 124,125].

This review has some limitations. First, most of the studies are cross-sectional, not trials or efficacy evaluation, which would be of particular interest to the researches, in order to understand the determinants of occupational diseases and to set up appropriate interventions. Among included publications, there is a high level of heterogeneity in terms of number of exposed subjects (some research concerns a limited number of residents) and length of exposure (from a few months to many years for others). Finally, it was very complex to compare very different studies, by environmental contexts very different for culture, religion and legislation.

5. Conclusions

Considering the constantly growing trend of new sources of noise and the particular susceptibility of people, caused by numerous factors, it is becoming increasingly urgent to define the extent of noise exposure, its severity and the correlation between sound input and the deterioration of the quality of life caused in the population. In 2005, the European Commission dedicated the European Week on Workplace Health and Safety to noise, developing numerous information and communication initiatives aimed at raising public awareness of this risk agent. In order to address the problem of environmental noise with lasting solutions, it is therefore necessary to achieve a quantification of the biological effects of external noise, both to foresee new socio-economic impacts in the health sector, and to develop new policy strategies and guidelines, aimed at easing the severity of the problem, and, in the medium to long term, achieving who targets. To do this, it is clear that socio-acoustic surveys are an indispensable tool for standardizing the correlation between noise reactivity and the extent of provocative noise.

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