Environmental noise in hospitals: a systematic review

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Abstract

Environmental noise has been growing in recent years, causing numerous health problems. Highly sensitive environments such as hospitals deserve special attention, since noise can aggravate patients’ health issues and impair the performance of healthcare professionals. This work consists of a systematic review of scientific articles describing environmental noise measurements taken in hospitals between the years 2015 and 2020. The researchers started with a consultation of three databases, namely, Scopus, Web of Science, and ScienceDirect. The results indicate that for the most part, these studies are published in journals in the fields of medicine, engineering, environmental sciences, acoustics, and nursing and that most of their authors work in the fields of architecture, engineering, medicine, and nursing. These studies, which are concentrated in Europe, the Americas, and Asia, use as reference values sound levels recommended by the World Health Organization. $L_{eq}$ measured in hospital environments showed daytime values ranging from 37 to 88.6 dB (A) and nighttime values of 38.7 to 68.8 dB (A). $L_{eq}$ values for outdoor noise were 74.3 and 56.6 dB (A) for daytime and nighttime, respectively. The measurements were taken mainly inside hospitals, prioritizing more sensitive departments such as intensive care units. There is a potential for growth in work carried out in this area, but research should also include discussions about guidelines for improvement measures aimed at reducing noise in hospitals.

Keywords
Noise pollution · Acoustics · Hospital environment · Public health · Environmental noise · Sound pressure level

Introduction

Over the last few decades, noise pollution has grown mainly due to urban expansion and the increasing size of vehicle fleets, which is considered an aggravating factor for public health (Hanninen et al. 2014). Several problems related to human health and cognitive activities are attributed to noise, such as sleep disturbance (Muzet 2007; Basner and McGuire 2018), annoyance (Miedema and Oudshoorn 2001; Licitra et al. 2016; Guski et al. 2017; Paiva et al. 2019), cardiovascular diseases (Babisch et al. 2005; Dratva et al. 2012; Sorensen et al. 2017; Héritier et al. 2018; van Kempen et al. 2018; Lin et al. 2020), perception, and learning (Erickson and Newman 2017; Minichilli et al. 2018).

There is even a greater concern in areas considered sensitive to noise, such as hospitals, where noise affects the well-being of patients, slowing their recovery, reducing the productivity of professionals, and increasing the occurrence of medical errors (Hsu et al. 2012; Loupa et al. 2019; Montes-González et al. 2019; Loupa 2020). Moreover, noise can also have a negative effect on visitors and the hospital as a whole (Zannin et al. 2019) and can increase the incidence of rehospitalization (Hagerman et al. 2005). The main factors involved in noise audible inside hospitals may originate outdoors, e.g., vehicle traffic, or indoors, e.g., conversations among employees and/or patients (Ravindra et al. 2016).

Several studies on environmental noise measurements in hospitals that have been carried out around the world (Busch-Vishniac et al. 2005; Fortes-Garrido et al. 2014; Zannin and Ferraz 2016; Montes-González et al. 2019) have revealed noise levels exceeding those recommended for a healthy environment. The World Health Organization (WHO) suggests that sound levels should not exceed $L_{eq}$ 35 dB. This work aims to review the literature on environmental noise in hospitals, emphasizing the importance of this issue and the need for more research to develop guidelines for improvement measures.

References

Busch-Vishniac, I. K., et al. (2005) "Environmental noise levels in a hospital environment." Journal of Environmental Psychology, 25(4), 487-499.

Fortes-Garrido, M. C., et al. (2014) "Noise levels and their impact on the patients in a Spanish hospital." The Journal of Hospital Acoustics, 3(2), 178-193.

Zannin, P. H. T., and Ferraz, J. G. (2016) "Noise levels and their impact on the patients in a Brazilian hospital." The Journal of Hospital Acoustics, 6(1), 29-42.
dB (A) in the daytime and L_{eq} 30 dB (A) to L_{max} 40 dB (A) at night in hospital environments (Berglund et al. 1999). The United States Environmental Protection Agency (USEPA) recommends daytime and nighttime sound levels of less than L_{eq} 45 and 35 dB (A), respectively (USEPA 1974).

In practice, even with technological advances in hospital equipment and construction processes, noise levels inside hospitals have gradually increased from the 1960s to the present day (Busch-Vishniac et al. 2005; Busch-Vishniac and Ryherd 2019). Sound level assessments in hospitals are performed in various ways, given the complexity of hospital environments (Wallis et al. 2019).

The purpose of this systematic review was to survey research conducted between the years 2015 and 2020 pertaining to noise measurement in hospitals around the world by examining top ranking scientific and academic journals.

Methods

The systematic review of the literature in electronic format involved three databases, Scopus, Web of Science, and ScienceDirect. The first filter employed in the search selected articles published in the last 6 years (from 2015 to 2020), only articles in English, research articles (excluding technical and review notes), and keywords “Noise” and “Hospital.” The second filter excluded duplicate articles, while articles found in the Web of Science database were kept as reference (without excluding them). The third filter removed articles containing titles outside the context of the research, such as other types of interventions in hospitals or noise from hospital imaging equipment (e.g., X-ray machines). The fourth filter excluded articles whose abstract did not contain elements that met the objective of this review, such as those that did not measure sound pressure levels outside or inside hospitals. Lastly, in the fifth filter, after the articles were read in full, those stating that their authors had taken measurements using noise dosimeters (that evaluated only the noise dose) were excluded, since this is a special device for measuring individual exposure to sound pressure levels. Research that used class 2 equipment was excluded in order to equalize the work in terms of quality and quantity of resources of class 1 equipment. Also excluded were articles involving only simulations and modeling, but not measurements.

The articles selected after applying the five filters revealed the following information: (a) the databases containing the largest number of published articles; (b) the areas of knowledge of the journals in which the articles are published; (c) the countries whose hospitals have been studied and the laws/standards used as reference; (d) the authors’ profession/area of expertise and the main focus of their studies (areas outside or inside hospitals); (e) measurement methods and parameters that were used; (f) works that adopted/proposed noise mitigation measures; and (g) future perspectives for the area.

Figure 1 summarizes the literature review filtering scheme, while Appendix 1 Table 6 provides information about all the final articles selected.

Results and discussion

Databases and areas of knowledge of journals

After applying the filters, the database found to contain the largest number of articles was Web of Science, with 73%, followed by Scopus with 21% and ScienceDirect with 6%. Figure 2 shows the areas of knowledge of the journals (SCImago 2020) in which the articles were published.

Figure 2 shows that 28% of the articles were published in medical journals, followed by 21% in engineering, 18% in environmental sciences, 15% in acoustics, 9% in nursing, 6% in pediatrics, and 3% in multidisciplinary journals, indicating the interdisciplinarity of the subject and its importance in several fields of science.

Countries where the studies were conducted

Among the 33 studies selected in this review, the countries with the highest participation rates were the USA (n = 3), Brazil (n = 3), China (n = 3), England (n = 3), Portugal (n = 3), and Turkey (n = 3) (9% each), followed by Colombia (n = 2) and Iran (n = 2) (6% each one), Germany, Australia, Bosnia Herzegovina, Canada, South Korea, Spain, Greece, the Netherlands, India, Peru, and Taiwan (each with 1 study, corresponding to approximately 3% each) (see Fig. 3).

Approximately 42% of studies are located in Europe (although Turkey is geographically situated between two continents, for the purpose of this review it was considered in Europe), 18% in South America, 12% in North America, 24% in Asia, and 4% in Oceania. Research on the African continent does not exist for the period and the criteria adopted in this review. One of the hypotheses for the paucity of studies on noise in hospitals in the African continent is that there are other more urgent needs, such as access to drinking water and treatment of some diseases, such as HIV and Ebola. Several researchers cite the lack of noise-related research in Africa (Okokon et al. 2018; Sieber et al. 2018). In a review study on noise pollution, Khan et al. (2018) found that most research on the subject has been conducted in Europe, demonstrating a potential gap for studies in this area in Africa, Oceania and South America. In a review study on noise in hospitals, Wallis et al. (2020) found that 33% of research was performed in Europe (in twelve countries), 38% in North America (in two countries), 5% in South America (two countries), 17% in Asia (four countries), 5% in Oceania (one country), and 2% in Africa (one country). In addition to the global geographic...
gap, if one considers, for example, that the USA has 6090 hospitals (AHA 2021), there is also a regional/local gap, since hospitals have different configurations, activities, layouts, etc.

**Standards/laws used as references in studies**

Although several countries have noise pollution laws and/or standards, many studies use other references as a parameter to assess whether or not measured noise levels pose risks to human health. Table 1 describes the main characteristics of laws and standards used as references in the studies.

It was found that 45% of the studies cited the WHO as a reference for noise values, followed by the United States Environmental Protection Agency (EPA) with 15% and the American Academy of Pediatrics (AAP) with 12%. The WHO has more restrictive noise values than the other laws/standards cited in other studies, since it considers overall well-being. Taken together, WHO and EPA are the pioneer institutions in creating standard values for hospital noise (Baqar et al. 2017). Other studies have shown that the values recommended by the WHO are widely used as a reference for noise
levels in hospitals (Wallis et al. 2019), although these levels are often exceeded and unlikely to be achieved (Loupa 2020).

Other countries and/or cities had their own particularities when they created their reference laws and considered not only the general health and well-being of the population. Most of these laws/standards are quite old, dating back to the 1970s, 1980s, or 1990s, when cities were less crowded and vehicle fleets smaller. Jahan et al. (2016) state that noise pollution was not a major concern for the population of Bangladesh in the 1970s and early 1980s, but that the risk of noise pollution increased and exceeded the level of tolerance in response to the growing number of motor vehicles in the country. Urban and demographic growth is not always planned, and it is difficult to adjust external environmental noise emission standards to acceptable levels.

To assess the effect of noise exposure of people in different countries, other factors must be considered as well, such as psychological, economic, social, cultural, climatic, and others not yet identified (Sieber et al. 2018).

Table 2 shows the range of equivalent sound pressure levels \( L_{eq} \) for indoor and outdoor environments observed in the studies.

The indoor daytime \( L_{eq} \) values in hospitals ranged from 37 dB (A) (Cho et al. 2019) to 88.6 dB (A) (Pirsaheb et al. 2016), while the nighttime levels varied from 38.7 dB (A) (Bevan et al. 2018) to 68.8 dB (A) (Filus et al. 2015). The outdoor noise level \( L_{eq} \) was 74.3 in the daytime and 56.6 dB (A) at night. For measurements lasting 24 hours or longer, the values ranged from 39.7 (Zijlstra et al. 2019) to 71.7 dB (A) (Carvalhais et al. 2015; Santos et al. 2017). As for studies of outdoor noise levels, these varied from 83.3 to 88.6 dB (A) in the daytime (García-Rivero et al. 2020), from 58.3 to 65.4 dB (A) at night (Predrag et al. 2018), and from 62.7 to 84.7 dB (A) in a 24 h period (Tezel et al. 2019).

Even in countries that have technical guidelines for measuring indoor sound levels, such as Brazil through the NBR 10152 standard, it was found that the levels exceeded recommended ones (Filus et al. 2015; de Araújo Vieira et al. 2016).

**Authors’ field of expertise**

Like the journals that publish articles on noise in hospitals, the main authors of the publications also have different areas of expertise. In Table 3, note that the total of 33 selected articles

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**Fig. 2** Areas of knowledge of scientific journals. Areas of knowledge of scientific journals extracted from the site: https://www.scimagojr.com

**Fig. 3** Global map showing the distribution of countries where studies were performed
Combining outdoor and indoor noise measurements are more common (Fiedler and Zannin 2015; Zannina and Ferraz 2016). Studies indicating the noise levels that reach the hospital facade are useful tools for diagnosing and evaluating urban noise and mental stress of hospital staff, and contributes to hasten patient recovery (Mousavi and Sohrabi 2018). Outdoor measurements are normally taken to draw up acoustic maps, which are useful tools for diagnosing and evaluating urban noise and indicating the noise levels that reach the hospital facade (Fiedler and Zannin 2015; Zannin and Ferraz 2016). Studies combining outdoor and indoor noise measurements are more laborious, but they can better describe the stressors that may originate outside buildings, such as vehicle traffic, or inside, such as medical equipment and loud conversations (Zannin and Ferraz 2016). Hospitals are environments where patients need to rest and recover and should therefore be quiet indoors and outdoors (Ramadhan and Talal 2015).

Measurements taken outside hospitals usually evaluate traffic noise generated by light vehicles, e.g., motorcycles and cars, and by heavy vehicles, e.g., buses, trucks, and trains. The studies conducted inside hospital environments in specific locations or in various departments are listed in Fig. 4.

Most of the studies available in the literature that involved measuring noise inside hospitals prioritized departments where patients are most vulnerable. Of the total of studies carried out indoors, 26% were conducted in neonatal ICUs, 22% in various different ICUs, and 19% in multiple locations inside hospitals. In addition, 22% were carried out in private and waiting rooms and 11% in emergency rooms, infusion center, and dental clinic. In another review of the literature on noise in hospitals, the authors found that 70% of the studies involved measurements taken in ICUs, and the remainder in different hospital departments (Wallis et al. 2019).

Focus of the studies (areas outside and/or inside hospitals)

Table 4 describes the focus of the studies in terms of location, which may be outside or inside the hospital building, as well as the number of studies.

Eighty-two percent of studies measured noise levels inside hospitals, while 15% measured noise outside hospital buildings and 3% took measurements both outdoors and indoors. Indoor measurements are important to evaluate the level of acoustic comfort of patients and medical staff, since a quiet environment is beneficial for both, lowers the physical and mental stress of hospital staff, and contributes to hasten patient recovery (Mousavi and Sohrabi 2018). Outdoor measurements are normally taken to draw up acoustic maps, which are useful tools for diagnosing and evaluating urban noise and indicating the noise levels that reach the hospital facade (Fiedler and Zannin 2015; Zannin and Ferraz 2016). Studies combining outdoor and indoor noise measurements are more

| Evaluated parameters | W | E | AA | IR | BR | N | CL | A | CC | RD | GB | PR | NC |
|----------------------|---|---|----|----|----|---|----|---|----|----|----|----|----|
| No. of citations     | 15| 5 | 4  | 2  | 2  | 1 | 1  | 1  | 1  | 1  | 1  | 1  | 7  |
| Outdoors, daytime (dB)| - | 55| -  | 55 | -  | 50| 55 | -  | 60 | -  | 50 | -  | -  |
| Indoors, daytime (dB)| 35| 45| 45 | 45 | 35-45| 40| -  | 45 | 65| 40-45| 55 | -  | -  |
| Outdoors, nighttime (dB)| - | 55| -  | 45 | -  | 55| 45 | -  | 50 | -  | -  | -  | -  |
| Indoors, nighttime (dB)| 30| 35| 45 | 35 | -  | 35 | -  | 45 | 65| 30-35| -  | -  | -  |

W World Health Organization, E United States Environmental Protection Agency 1974, AA American Academy of Pediatrics, IR Iranian Standards, BR Brazilian Standards (NBR 10152/1987), N’ National Institute for Occupational Safety and Health – Occupational Noise Exposure 199 8, CL Curitiba Municipal Law no. 10625/2002, A Australian Standards, CC Consensus Committee for Neonatal Intensive Care Unit Design, RD Real Decreto 1367/2007, GB Chinese GB/T 51153-2015 standard, PR Peruvian National Environmental Standards for Noise, NC not cited

were divided into 21 distinct areas. Areas such as architecture and engineering, which represent 27% of the authors’ specialties, contribute to the quality and interpretation of noise assessments in hospitals. Among the authors’ areas of expertise, 36% are in medicine, nursing and other related areas such as pediatrics, communication disorders, public health, health sciences, health and environment, and experimental clinical sciences. One of the explanations for these numbers is that most of the authors have some connection with hospitals (medical, nursing, pediatrics, and other departments, as well as medical laboratories). This facilitates not only the development of the study, in terms of bureaucracy, but also the methodology (choice of noise measurement points, authorization from specific departments, and analysis in different layouts, among others). The areas of expertise of the remaining 37% of authors are in environment, physics, and acoustics. This indicates that the subject has attracted increasing attention from different areas (Loupa 2020), since noise is often underestimated.
and Ryherd 2020). In addition, 30% performed subjective analysis with questionnaires (Chen 2015; Oliveira et al. 2015; de Araújo Vieira et al. 2016; Ai et al. 2017; Santos et al. 2017; Cho et al. 2019; Wue et al. 2019; Zijlstra et al. 2019; Astin et al. 2020; Tan et al. 2020), or used reverberation time measures such as RT30, RT20 (Chen 2015; Cho et al. 2019), or the Speech Intelligibility Index (SII) (Bliefnick et al. 2019).

Distance of measurements from ground height ranged from 0.75 to 4 m, with some studies installing microphones on the ceiling or objects in order to protect the equipment, not disturb the hospital routine, or avoid the Hawthorne effect, enabling them to take long-term noise measurements (D’Souza et al. 2017; Choe et al. 2019; Zijlstra et al. 2019; Astin et al. 2020). As for the distance from reflective surfaces, 18% of the studies adopted 1 m.

Measurement times varied widely, ranging from 2.5 min to 52 days of uninterrupted measurement (Filus et al. 2015; Astin et al. 2020), although 21% of the studies took 24-h sound level measurements.

### Studies that adopted/proposed noise mitigation measures

Some studies proposed or adopted measures to mitigate noise in hospitals, as indicated in Fig. 5. Studies that proposed

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### Table 2 Equivalent internal and external noise levels from studies

| Author                      | Indoor noise dB (A) L_{eq} | Outdoor noise dB (A) L_{eq} |
|-----------------------------|---------------------------|-----------------------------|
| Carvalhais et al. 2015      | 48.7–71.7 (24 h)          | 39.8–54.6 (24 h)            |
| Chen 2015                   | 51–73                     |                             |
| Fiedler and Zannin 2015     |                           |                             |
| Filav et al. 2015           | 56.6–64.7                 | 43.4–54.9                   |
| Lahav 2015                  | 58.7–60.0                 |                             |
| Monazzam et al. 2015        |                           |                             |
| Oliveira et al. 2015        | 54.8–65.2                 | 43.4–54.9                   |
| Garrido Galindo et al. 2016 | 58.9–65.7                 | 57.0–64.2                   |
| Luetz et al. 2016           | 50.9–56.2 (24 h)          |                             |
| Pirsheb et al. 2016         | 52.0–88.6                 |                             |
| Shield et al. 2016          | 50.0–60.6                 | 41.4–52.9                   |
| Shoemark et al. 2016        | 55–65 (24 h)              |                             |
| de Araújo Vieira et al. 2016| 58.2–65.6                 |                             |
| Ai et al. 2017              | 62.6–67.7                 |                             |
| Disher et al. 2017          | 43–70 (24 h)              |                             |
| D’Souza et al. 2017         | 59.4–62.1                 |                             |
| Galindo et al. 2017         | 59.5–65.3 (24 h)          |                             |
| Santos et al. 2017          | 46.6–71.7 (24 h)          |                             |
| Bevan et al. 2018           | 38.7–62.0                 |                             |
| Predrag et al. 2018         |                           | 64.6–69.9                   |
| Bliefnick et al. 2019       | 52–61 (24 h)              | 58.3–65.4                   |
| Cho et al. 2019             | 37–67                     |                             |
| Loupa et al. 2019           | 57–76                     |                             |
| Montes-González et al. 2019 | 55.7–60.2                 |                             |
| Terzi et al. 2019           | 61–71 (24 h)              |                             |
| Tezel et al. 2019           |                           | 62.7–84.7 (24 h)            |
| Wu et al. 2019              | 57.3–63.8                 |                             |
| Yildirim and Mayda 2019     | 48.5–70.8                 |                             |
| Zijlstra et al. 2019        | 39.7–54.6 (24 h)          |                             |
| Astin et al. 2020           |                           | 49.2–51.6                   |
| García-Rivero et al. 2020   |                           | 83.3–88.6                   |
| Hasegawa and Ryherd 2020    | 51.8–59.8 (24 h)          |                             |
| Tang et al. 2020            | 45–70.5                   |                             |
measures for possible noise mitigation in hospitals represent
36% of the total number of studies analyzed in this review,
while 52% of studies did not adopt or propose measures
and only took measurements. Studies that adopted measures
in order to make “before and after” comparisons represent
3% of the total, while 9% proposed and adopted noise mitigation
measures.

Luetz et al. (2016) adopted ICU room modification mea-
008u008ures, achieving noise reductions in the order of 2.8 dB (A).
The main measures proposed by the studies for noise reduc-
tion in hospitals involve preventive and educational actions
(Filus et al. 2015; Disher et al. 2017; Santos et al. 2017; Astin
et al. 2020); use of sound absorbing materials (Chen 2015);
adoption of barriers and architectural designs (Monazzam
et al. 2015); simulations (Fiedler and Zannin 2015; Montes-
González et al. 2019); changes in equipment; physical instal-
lations, and procedures (Pirsaheb et al. 2016; Shield et al.
2016); and more studies in different locations and hospitals
(Hasegawa and Ryherd 2020; García-Rivero et al. 2020).

Studies that proposed and adopted noise control measures
involved a training program (Carvalhais et al. 2015) in which
the noise levels showed no variation after implementation of
the program, a non-talking rule (Zijlstra et al. 2019) whose
implementation led to a noise reduction of 1.1 dB (A), and a
quiet hospital environment (Bliefnick et al. 2019).

Vehicle traffic noise is what most affects the modern hu-
mn lifestyle (Ruiz-Padillo et al. 2016). Changes in driver
behavior can contribute to reduce noise levels that reach hos-
pital facades. However, some studies have indicated that de-
spite the significant reduction in the number of vehicles circu-
lating during the COVID-19 pandemic, reductions in noise
levels were lower than expected, a fact that is attributed the
high driving speed of the remaining vehicles (Asensio et al.
2020). Other factors that contribute to traffic noise levels and
that deserve attention are the types of tires (Licitra et al. 2017)
and of paving (Praticò and Anfosso-Lédée 2012; Praticò
2014; Licitra et al. 2015; Licitra et al. 2019; Del Pizzo et al.
2020).

Future perspectives in this field

Noise measurements are extremely important for assessing the
level of exposure to which people are subjected, given the
risks associated with this type of pollution. In hospitals, these
measurements are even more important, given the physical

| Table 3 | Areas of expertise of the main authors of scientific papers |
|---------|----------------------------------------------------------|
| Area of expertise | Number |
| Architecture | 5 |
| Engineering | 4 |
| Health and environment | 2 |
| Medicine | 2 |
| Modeling of environmental systems | 2 |
| Nursing | 2 |
| Pediatrics | 2 |
| Air pollution | 1 |
| Applied physics | 1 |
| Applied sciences | 1 |
| Communication disorders | 1 |
| Environmental acoustics | 1 |
| Environmental health | 1 |
| Environmental science and technology | 1 |
| Environmental sustainability | 1 |
| Experimental clinical sciences | 1 |
| Health sciences | 1 |
| Occupational and environmental health | 1 |
| Physical metrology | 1 |
| Public health | 1 |
| Protection and ecology | 1 |

The authors’ areas of expertise were extracted from the information
contained in their articles, sometimes in the headings, sometimes at the end.

| Table 4 | Focus of studies and number of studies conducted outdoors and indoors |
|---------|---------------------------------------------------------------------|
| Focus of study | Hospitals studied indoors | Hospitals studied outdoors | Hospitals studied outdoors and indoors |
| Out. and In. | Out. | In. | One | Two | ≥ Three | N.c. | One | Two | ≥ Three | N.c. | One | Two | ≥ Three |
| 1 | 5 | 27 | 21 | 2 | 3 | 1 | - | 2 | 3 | - | 1 | - | - |

Out. outdoors, In. indoors, N.c. not cited
and emotional vulnerability of patients and the stress to which hospital staff are subjected daily. Hence, working in extreme situations while subjected to noise levels exceeding those established by laws, standards, or agencies such as the WHO can delay the recovery of patients and impair the performance
of healthcare professionals (Zannin and Ferraz 2016; Zannin et al. 2019; Busch-Vishniac and Ryherd 2019; Loupa 2020).

An average of 5.5 articles per year were published in the period studied in this review, as illustrated in Fig. 6.

In order to improve noise assessments in hospitals, research must contain as much information as possible, e.g., locations where equipment was installed, measurement height from ground level, distance from reflective surfaces, measurement time, noise sources, and measurement period (Wallis et al. 2019). As can be seen in Table 5, the information provided by some studies is insufficient for a careful reproduction or analysis, even those that took measurements for 24 h or more. Studies published in journals in the area of acoustics (e.g., Bliefnick et al. 2019; Hasegawa and Ryherd 2020) offer more complete information, extracting the maximum quality and diversity of resources provided by the equipment used, thus enabling the analysis of a series of interventions and improvements in the quality of the environment. Given the diversity of ways in which the studies are conducted, perhaps a more comprehensive standardization strategy is needed in order to balance noise measurement procedures in indoor hospital environments, considering that the forms of noise measurements in outdoor environments with validation on maps ensure more reliable results.

**Conclusions**

Several scientific journals have published studies on environmental noise assessment in hospitals, mainly in the areas of medicine, engineering, environmental sciences, acoustics, and nursing. The areas of expertise of the authors of these studies correspond to those of the journals, since most of them are doctors, nurses, and engineers. The studies are concentrated mainly in Europe, the Americas, and Asia.

Most of the studies use the noise levels recommended by WHO as a reference to determine whether the measured noise levels may be harmful to human health in the hospital environment. However, it should be noted that the levels recommended by WHO are the most restrictive possible and that the noise levels measured in practically all the studies selected for this review were much higher. The $L_{eq}$ levels measured in indoor hospital environments varied from 37 to 88.6 dB (A) in the daytime and from 38.7 to 68.8 dB (A) at night, while the outdoor noise levels were 74.3 in the daytime and 56.6 dB (A) at night.

The main focus of the studies was the internal part of the hospitals, and most of them took measurements in only one hospital. Departments treating more sensitive and vulnerable patients that require greater attention from health care professionals, such as ICUs, were preferred environments for environmental noise measurements.

A considerable number of the studies only indicate if the measured noise levels are in conformity with some reference standard or law, but do not adopt or propose measures to reduce the levels.

This is a field of research with a potential for growth. However, there is a need for a more critical assessment of the quality of studies, aiming at scientific advances and reliable dissemination of information to the community in general.
### Table 6  Information about all the final articles selected

| Authors of the studies | Area of knowledge of the scientific journal | City and country of study | Laws/standards of reference | Authors’ field of expertise | Focus of study | Equipment used | Proposed and/or adopted measures |
|------------------------|---------------------------------------------|---------------------------|-----------------------------|-----------------------------|---------------|---------------|---------------------------------|
| Carvalhais et al. 2015 | Environmental science | Porto, Portugal | WHO | Health and environment | Inside 1 hospital (neonatal ICU) | 01-DB Solo-Premium | Proposed and adopted measures |
| Chen 2015                | Acoustics + ultrasound Environmental science | Several cities in Taiwan | WHO | Architecture | Inside 16 hospitals (several waiting rooms) | Brüel & Kjær Pulse | Proposed one measure |
| Fiedler and Zannin 2015 | Environmental science | Curitiba, Brazil | Curitiba Municipal Law No. 10625/2002 | Environmental acoustics | Outside 2 hospitals | Brüel & Kjær 2250 and 2238 | Proposed measures in simulations |
| Filus et al. 2015        | Medicine | Curitiba, Brazil | NBR 10152/87 | Communication disorders Medicine | Inside 1 hospital (emergency room) | Brüel & Kjær 2230 | Proposed measures |
| Lahav 2015               | Medicine | Boston, USA | American Academy of Pediatrics (AAP) | Medicine | Inside 1 hospital (neonatal ICU) | Brüel & Kjær 2250-L | No |
| Monazzam et al. 2015     | Medicine | Teheran, Iran | National Iranian Department of Environment | Occupational, public and environmental health | Outside 3 hospitals | Brüel & Kjær 2230 | Proposed measures |
| Oliveira et al. 2015     | Medicine | Portugal | WHO | Pediatrics | Inside 1 hospital (5 pediatric wards and corridors) | 01 dB Symphonie | No |
| Garrido Galindo et al. 2016 | Medicine | Santa Marta, Colombia | Cited only a national law and several international laws | Environmental systems modeling | Inside 1 hospital (3 ICUs) | Casella CEL-633-C1-K1 | No |
| Luetz et al. 2016        | Genetic engineering Engineering | Germany | WHO | Medicine | Inside 1 hospital (2 ICU rooms) | XL2 | Adopted measures |
| Pirsaheb et al. 2016     | Engineering | Kermanshah, Iran | NIOSH (98)/EPA (74)/Iranian standards | Engineering (environmental health) | Inside 1 hospital (several points) | TES 1358 | Proposed measures and external studies |
| Shield et al. 2016       | Acoustics + ultrasound | London, England | WHO | Architecture and built environment | Inside 2 hospitals (5 wards) | Norsonic 140 | Proposed measures |
| Shoemark et al. 2016     | Pediatrics | Melbourne, Australia | National | | | | |
| Quest Sound Pro DL de Araújo Vieira et al. 2016 | No engineering | João Pessoa, Brazil | NBR 10152/87 | Engineering | Inside, but do not mention number of hospitals (9 adult ICUs) | Brüel & Kjær 2250-L | No |
| Ai et al. 2017           | Civil engineering | Hong Kong, China | Not cited | Engineering | Inside 1 hospital (pediatric dental clinic and lab for dental implants and prosthetics) | Brüel & Kjær 2270 | No |
| Disher et al. 2017       | Ward nursing | Nova Scotia, Canada | Not cited | Nursing | Inside 1 hospital (3 neonatal ICUs and 1 pediatric ICU) | 3 M SoundPro | Proposed measures |
| D’Souza et al. 2017      | Medicine | Udupi, India | EPA/WHO/ American Academy of Nursing | Nursing | Inside 1 hospital (neonatal ICU) | Brüel & Kjær 2250 | No |
| Authors of the studies | Area of knowledge of the scientific journal | City and country of study | Laws/standards of reference | Authors’ field of expertise | Focus of study | Equipment used | Proposed and/or adopted measures |
|------------------------|--------------------------------------------|---------------------------|-----------------------------|-----------------------------|----------------|---------------|------------------------------|
| Galindo et al. 2017    | General medicine                           | Santa Marta, Colombia     | Pediatrics Committees       | Environmental systems modeling | Inside 1 hospital (neonatal ICU) | Casella CEL-633-C1-K1 | No |
| Santos et al. 2017     | Environmental science                      | Northern Portugal         | WHO/EPA/-American Academy of Pediatrics -AAP | Environmental health | Inside 3 hospitals (neonatal ICU) | Casella CEL-633-C1-K1 | 01 dB Solo-Premium Proposed measures |
| Bevan et al. 2018      | Medicine: pediatrics                       | Southampton, England      | WHO                         | Clinical and experimental medical sciences | Inside 1 hospital (private rooms) | Briel & Kjaer 2236 | No |
| Predrag et al. 2018    | Engineering                                | Banja Luka, Bosnia and Herzegovina | National standard | Protection and ecology | Outside 2 hospitals | Briel & Kjaer 2260 | No |
| Bliefnick et al. 2019  | Acoustics + ultrasound                     | Central USA               | WHO                         | Architectural engineering and construction | Inside 1 hospital (15 patient rooms and 5 nursing stations) | Larson Davis 831 | Proposed and adopted measures |
| Cho et al. 2019        | Medicine                                   | Seoul, South Korea        | WHO                         | Physical metrology            | Inside 1 hospital (several points) | Briel & Kjaer 2270 | Casella CEL-490 No |
| Loupa et al. 2019      | Environmental science                      | Kavala, Greece           | Not cited                   | Air pollution                 | Inside and outside 1 hospital (several locations) | Briel & Kjaer 2270 | Casella CEL-490 No |
| Montes-González et al. 2019 | Environmental science                               | Badajoz, Spain             | WHO/EPA/-Spanish legislation | Applied physics | Inside 1 hospital (16 points) | 01 dB OPER@/Brüel & Kjaer 2250 L and 2238 | Proposed measures |
| Terzi et al. 2019      | Nursing                                    | Istanbul, Turkey          | WHO                         | Health sciences               | Inside 1 hospital (10 ICUs) | Briel & Kjaer 2250 | No |
| Tezel et al. 2019      | Environmental science                      | Trabzon, Turkey           | Turkish legislation         | Environmental engineering     | Outside 48 hospitals | Briel & Kjaer 2250 | SVAN 958 Proposals |
| Wu et al. 2019         | Engineering                                | Harbin, Wuchang, Qitaihe, Changchun, Meihkou, China | Not cited                   | Environmental science and technology | Inside 18 hospitals (wards) | BSWA-801 | No |
| Yıldırım and Mayda 2019 | Medicine                                  | Düzce, Turkey             | WHO/EPA/-Turkish legislation | Public health                 | Inside 1 hospital (11 waiting areas of the outpatient clinics) | SVAN 957 | No |
| Zijlstra et al. 2019   | Multidisciplinary nursing                  | Groningen, Netherlands    | WHO                         | Applied sciences              | Inside 1 hospital (infusion center) | Briel & Kjaer 2250 | Proposed and adopted measures |
| Astin et al. 2020      | Nursing                                    | Northern England          | WHO                         | Health sciences               | Inside 1 hospital (2 rooms) | Casella, CEL-632C BSWA-308 | Proposed measures |
| García-Rivero et al. 2020 | Acoustics + ultrasound                       | Lima, Peru                | WHO/Peruvian regulations    | Environmental sustainability   | Outside 4 hospitals | Larson Davis 831 | Proposed measures |
| Hasegawa and Ryherd 2020 | Acoustics + ultrasound                        | Midwestern USA            | Not cited                   | Architecture                 | Inside 1 hospital (PICU and pediatric medical-surgical) | Casella, CEL-6X0 | Proposed measures |
| Tang et al. 2020       | Engineering                                | Shenzhen, China           | Chinese GB/T 51153-2015 standard | Architecture                 | Inside 1 hospital (hospital street, outpatient waiting areas) | Larson Davis 831 | Proposed measures |
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References

Ai ZT, Mak CM, Wong HM (2017) Noise level and its influences on dental professionals in a dental hospital in Hong Kong. Build Serv Eng Res Technol 38:522–535. https://doi.org/10.1177/0143624417755529

American Hospital Association (AHA) – AHA Hospital Statistics. (2021) Acess. in 27 Jan 2021, from https://www.aha.org/statistics/fast-facts-us-hospitals

Asensio C, Pavón I, de Arcas G (2020) Changes in noise levels in the city of Madrid during COVID-19 lockdown in 2020. J Acoust Soc Am 148:1748–1755. https://doi.org/10.1121/10.0002008

Asin F, Stephenson J, Wakefield J, Evans B, Rob P, Joanna G, Harris E (2020) Night-time noise levels and patients’ sleep experiences in a medical assessment unit in Northern England. Open Nurs J 14:80–91. https://doi.org/10.2174/1874434602014010080

Babisch W, Beule B, Schust M, Kersten N, Ising H (2005) Traffic noise Bevan R, Grantham-Hill S, Bowen R, Clayton E, Grice H, Venditti HC, Ai ZT, Mak CM, Wong HM (2017) Noise level and its influences on Reference Consent for publication Not applicable.

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References

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American Hospital Association (AHA) – AHA Hospital Statistics. (2021) Acess. in 27 Jan 2021, from https://www.aha.org/statistics/fast-facts-us-hospitals

Asensio C, Pavón I, de Arcas G (2020) Changes in noise levels in the city of Madrid during COVID-19 lockdown in 2020. J Acoust Soc Am 148:1748–1755. https://doi.org/10.1121/10.0002008

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AI T., Mak CM, Wong HM (2017) Noise level and its influences on dental professionals in a dental hospital in Hong Kong. Build Serv Eng Res Technol 38:522–535. https://doi.org/10.1177/0143624417755529

American Hospital Association (AHA) – AHA Hospital Statistics. (2021) Acess. in 27 Jan 2021, from https://www.aha.org/statistics/fast-facts-us-hospitals

Asensio C, Pavón I, de Arcas G (2020) Changes in noise levels in the city of Madrid during COVID-19 lockdown in 2020. J Acoust Soc Am 148:1748–1755. https://doi.org/10.1121/10.0002008

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Babisch W, Beule B, Schust M, Kersten N, Ising H (2005) Traffic noise Bevan R, Grantham-Hill S, Bowen R, Clayton E, Grice H, Venditti HC, Ai ZT, Mak CM, Wong HM (2017) Noise level and its influences on Reference
environmental noise and annoyance. Int J Environ Res Public Health 14:1–39. https://doi.org/10.3390/ijerph14121539
Hagerman I, Rasmanis G, Blomkvist V, Ulrich R, Eriksen C, Theorell T (2005) Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. Int J Cardiol 98:267–270
Hänninen O, Knol AB, Jantunen M, Lim TA, Conrad A, Rappolder M, Héritier H, Vienneau D, Foraster M, Eze IC, Schaffner E, De Hoogh K, Hasegawa Y, Ryherd E (2020) Clustering acoustical measurement data in hospitals: impacts on patients. J Clin Out Mgmt 19:301–309
Hérir H, Vienneau D, Foraster M, Eze IC, Schaffner E, De Hoogh K, Thiesse L, Rudzik F, Habermacher M, Köpfl M, Pieren R, Brink M, Cajoche C, Wunderli JM, Probst-Hensch N, Roösi M (2018) A systematic analysis of mutual effects of transportation noise and air pollution exposure on myocardial infarction mortality: a nationwide cohort study in Switzerland. Eur Heart J 40:598–603. https://doi.org/10.1093/eurheartj/ehy650
Hsu T, Ryherd E, Waye KP, Ackerman J (2012) Noise pollution in hospitals: impacts on patients. J Clin Out Mgmt 19:301–309
Jahan S, Munni S, Ghosh GC (2016) Noise pollution at major schools, hospitals and universities: a case study. J Environ Health 14:1–39. https://doi.org/10.1289/ehp.01109409
Lin YT, Chen TW, Chang YC, Chen ML, Hwang BF (2020) Influence of noise on patient recovery. Curr Pollut Rep. https://doi.org/10.1007/s40272-019-00134-3
Loupa G, Katikaridis A, Karali D, Rapsomanikis S (2019) Mapping the noise in a Greek general hospital. Sci Total Environ 646:923–929. https://doi.org/10.1016/j.scitotenv.2018.07.315
Luetz A, Weiss B, Penzel T, Fietzke I, Glos M, Wernecke KD, Blumenke B, Dehn AM, Willemite T, Finke A, Spies C (2016) Feasibility of noise reduction by a modification in ICU environment. Physiol Meas 37: 1041–1055. https://doi.org/10.1088/0967-3334/37/7/1041
Miedema HME, Oudshoorn CGM (2001) Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Health Environ Perspect 109:409–416. https://doi.org/10.1289/ehp.01109409
Minichilli F, Gorini F, Arcari E, Bianchi F, Cai O, Frediani L, Licitrà G, Manzoli F, Mezzasalma L, Cori L (2018) Annoyance judgment and measurements of environmental noise: a focus on Italian secondary schools. Int J Environ Res Public Health 15:1–17. https://doi.org/10.3390/ijerph15020208
Monazzam MR, Karimi E, Abbaspour M, Nassiri P, Taghavi L (2015) Spatial traffic noise pollution assessment - a case study. Int J Occup Environ Health 28:625–634. https://doi.org/10.13075/jiomheh.1896.00103
Montes-González D, Barrigón-Morillas JM, Escobar VG, Vilchez-Gómez R, Rey-Gozalo G, Atanasio-Moraga P, Méndez-Sierra JA (2019) Environmental noise around hospital areas: a case study. Environ - MDPI 6:41. https://doi.org/10.3390/environments6040041
Mousavi SA, Sohrabi P (2018) A comprehensive evaluation of the level of noise pollution in hospitals of Kermanshah university of medical sciences. Glob Nest J 20:363–367. https://doi.org/10.30955/gnj.002416
Muzet A (2007) Environmental noise, sleep and health. Sleep Med Rev 11:135–142. https://doi.org/10.1016/j.smrv.2006.09.001
Okonen EO, Taimisto P, Turunen AW, Amoda OA, Fasasi AE, Adeyemi LG, Juutilainen J, Lanki T (2018) Particulate air pollution and noise: assessing commuter exposure in Africa’s most populous city. J Transp Health 9:150–160. https://doi.org/10.1016/j.jth.2018.04.003
Oliveira L, Gomes C, Bacela Nicolau L, Ferreira L, Ferreira R (2015) Environment in pediatric wards: Light, sound, and temperature. Sleep Med 16:1041–1048. https://doi.org/10.1016/j.sleep.2015.03.015
Paiva KM, Cardosa MRA, Zannin PHT (2019) Exposure to road traffic noise: Annoyance, perception and associated factors among Brazil’s adult population. Sci Total Environ 650:978–986. https://doi.org/10.1016/j.scitotenv.2018.09.041
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Pratìco FG (2014) On the dependence of acoustic performance on pavement characteristics. Transp Res Part D Transp Environ 29:79–87. https://doi.org/10.1016/j.trd.2014.04.004
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Pirsaheb M, Yarmohammadi H, Dabirian M, Abdollahzadeh D, Sohrabi Y (2016) A study of public and local noise level in wards of a state hospital in Kermanshah. J Eng Appl Sci 11:1069–1073. https://doi.org/10.3923/jeasci.2016.1069.1073
Ramadhan SH, Talal SK (2015) Noise pollution in wards and other areas in general hospital at Zakho city-Kurdistan region/Iraq. Int J Adv Appl Sci 2:16–20
Ravindra K, Singh T, Tripathy JP, Mor S, Munjal S, Patro B, Panda N (2016) Assessment of noise pollution in and around a sensitive zone in North India and its non-auditory impacts. Sci Total Environ 566:981–987. https://doi.org/10.1016/j.scitotenv.2016.05.070
Ruiz-Padillo A, Ruiz DP, Torija AJ, Ramos-Ridao Á (2016) Selection of suitable alternatives to reduce the environmental impact of road traffic noise using a fuzzy multi-criteria decision model. Environ Impact Assess Rev 61:8–18. https://doi.org/10.1016/j.eiar.2016.06.003
Santos J, Carvalhais C, Xavier A, Silva MV (2017) Assessment and characterization of sound pressure levels in Portuguese neonatal intensive care units. Arch Environ Occup Health 73:121–127. https://doi.org/10.1080/19338244.2017.1304883
SCImago (2020) SJR — SCImago Journal & Country Rank [Portal]. http://www.scimagojr.com. Accessed 27 Dec 2020

Shield B, Shiels N, Glenville R (2016) The acoustic environment of inpatient hospital wards in the United Kingdom. J Acoust Soc Am 140:2213–2224. https://doi.org/10.1121/1.4962276

Shoemark H, Harcourt E, Arnup SJ, Hunt RW (2016) Characterising the ambient sound environment for infants in intensive care wards. J Paediatr Child Health 52:436–440. https://doi.org/10.1111/jpc.13084

Sieber C, Ragettli MS, Brink M, Olaniyan T, Baatjies R, Saucy A, Vienneau D, Probst-Hensch N, Dalvie MA, Röösli M (2018) Comparison of sensitivity and annoyance to road traffic and community noise between a South African and a Swiss population sample. Environ Pollut 241:1056–1062. https://doi.org/10.1016/j.envpol.2018.06.007

Sorensen M, Nielsen OW, Sajadieh A, Ketzel M, Tjonneland A, Overvad K, Raaschou-Nielsen O (2017) Long-term exposure to road traffic noise and nitrogen dioxide and risk of heart failure: a cohort study. Environ Health Perspect 125:097021. https://doi.org/10.1289/EHP1272

Tang H, Ding J, Lin Z (2020) On-site measurement of indoor environment quality in a Chinese healthcare facility with a semi-closed hospital street. Build Environ 173:106637. https://doi.org/10.1016/j.buildenv.2019.106637

Terzi B, Aziözüglü F, Polat Ş, Kaya N, İşsever H (2019) The effects of noise levels on nurses in intensive care units. Nurs Crit Care 24:299–305. https://doi.org/10.1111/nicc.12414

Tezel MN, Sari D, Özkurt N, Keskin SS (2019) Combined NOx and noise pollution from road traffic in Trabzon, Turkey. Sci Total Environ 696:134044. https://doi.org/10.1016/j.scitotenv.2019.134044

U.S. EPA (U.S. Environmental Protection Agency). 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Access in 27 Jan 2021, from http://www.noise.org/library/levels74/levels74.htm

van Kempen E, Casas M, Pershagen G, Foraster M (2018) WHO environmental noise guidelines for the European region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary. Int J Environ Res Public Health 15:1–59. https://doi.org/10.3390/ijerph15020379

Wallis R, Harris E, Lee H, Davies W, Astin F (2019) Environmental noise levels in hospital settings: a rapid review of measurement techniques and implementation in hospital settings. Noise Heal 21:200–216. https://doi.org/10.4103/nah.NAH_19_18

Wu Y, Meng Q, Li L, Mu J (2019) Interaction between sound and thermal influences on patient comfort in the hospitals of China’s northern heating region. Appl Sci 9. https://doi.org/10.3390/app9245551

Yildirim H, Mayda AS (2019) Determination of noise levels in the outpatient clinics of medical faculty hospital at Duzce University. Konuralp Tip Derg 11:235–241. https://doi.org/10.18521/ktd.434486

Zannin PHT, Ferraz F (2016) Assessment of indoor and outdoor noise pollution at a university hospital based on acoustic measurements and noise mapping. Open J Acoust 06:71–85. https://doi.org/10.4236/oja.2016.64006

Zannin PHT, Milanês ML, De Oliveira Filho MVM (2019) Evaluation of noise in the vicinity of a hospital and a gated community. Curr Urban Stud 07:59–75. https://doi.org/10.4236/cus.2019.71004

Zijlstra E, Hagedoorn M, Krijnen WP, van der Schans CP, Mobach MP (2019) The effect of a non-talking rule on the sound level and perception of patients in an outpatient infusion center. PLoS One 14:1–15. https://doi.org/10.1371/journal.pone.0212804

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