



Research Article

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Daytime perimeter environmental noise in the vicinity of four hospitals in the city of Lima, Peru

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Abstract: The present study is intended to get to know the levels of perimeter diurnal environmental noise of four hospitals in the city of Lima. The measurement mode used at each hospital was A-weighting, with an integration time of five minutes per recording. It was measured in the FAST mode with calibrations made at the beginning and end of the measurement day. Statistical analysis consisted of the mean comparison T test which was applied at all the hospitals considered in the study. At the four hospitals, at all the hours of measurement and both on working days and non-working days (Sunday), LAeq mean values are higher than 83 dBA. On working days, two periods of maximum noise from 08:00 to 10:00 in the morning and from 17:00 to 19:00 in the afternoon coincide with the start and end of working hours. The perimeter diurnal environmental noise levels determined at the vicinity of four hospitals show higher values in all cases to those established by the Peruvian National Environmental Standards for Noise for special protection areas both for working days and for non-working days. Noise that comes from the dense and disorganized traffic of Lima plays a fundamental role in this behaviour.

Keywords: Noise exposure, noise and health, vehicular traffic, hospitals

1 Introduction

In Lima, the predominant cause of noise pollution in perimeter areas of hospitals is vehicular traffic, followed by noise derived from various service centres and people talking loudly around hospitals. The results of the Agency for Evaluation and Environmental Control (OEFA) on noise pollution in Lima and Callao – 2015 showed that 90% of the points analysed exceed the environmental quality standard [1]. Similarly, the total vehicle flow rose 3.0% and that of heavy vehicles in Lima increased 2.3% during 2017, which points to a growth in vehicle noise [2]. Recent studies indicate biological effects of noise [3] and that exposure to high noise levels delays the recovery of patients in hospitals [4–6], because it may cause some degree of psychological and physical stress [7, 8], but it also affects the human nervous system and cardiovascular system [9, 10]. The impact of noise on the economy and the environment is also well known [11]. The growth of activities – mainly informal and formal trade – as well as urban transport has generated a noise-related air quality problem.

Depending on its duration and volume, the effects of noise on human health and comfort are divided into four categories: (a) Physical effects, such as hearing defects; (b) Physiological effects, such as increased blood pressure, ir-

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regularity of heart rhythms and ulcers; (c) Psychological effects, such as disorders, sleeplessness and going to sleep late, irritability and stress; and, finally, (d) Effects on work performance, such as reduction of productivity and misunderstanding of what is heard [12, 13]. The World Health Organization (WHO) suggests that average hospital sound levels should not exceed 35 dB with a maximum of 40 dB overnight.

Although Lima is classified as a very noisy city [1], current Peruvian regulations on noise establish the Maximum Permitted Limits for each type of area [14]. However, it is unknown whether these maximum permissible noise levels are respected in the perimeters of the most important hospital centres for paediatric and maternal and child care, which are classified in the category of special areas.

Taking these circumstances into account, the present study aims to characterize daytime perimeter environmental noise in the vicinity of four hospitals in the city of Lima based on direct instrumental determinations. These important health centres are located in areas with a high density of vehicular traffic, which makes it very likely that regulations regarding levels of environmental noise in their surroundings are not being met, with a possible potential impact within these centres.

To achieve this research objective, a network of points has been designed for the measurement of noise levels with a type I sound level meter during the different days of the week between 08:00 and 22:00 hours.

These measurements will allow for knowing the true perimeter noise levels to which a large part of the main health centres of Lima are exposed to.

2 Methodology

The developed project consists of applied research – as it has obtained for the first time – information on noise behaviour in the surroundings of four hospital centres of Lima.

It is an experimental investigation and the experiment includes the design of the points and modalities of noise sampling at each installation studied, both from the spatial and temporal point of view, the choice of the sound level meter and the measurement mode, and the processing and analysis of the information, following the National Protocol for Noise Monitoring, approved by Peruvian Ministerial Resolution No.227-2013 of the Peruvian Ministry of Environment (MINAM) [15].

2.1 Selection of the Institutions to be studied

There are ten hospitals belonging to the Peruvian Ministry of Health in Lima, but only four hospitals were selected for this project as they provide paediatric or maternal-

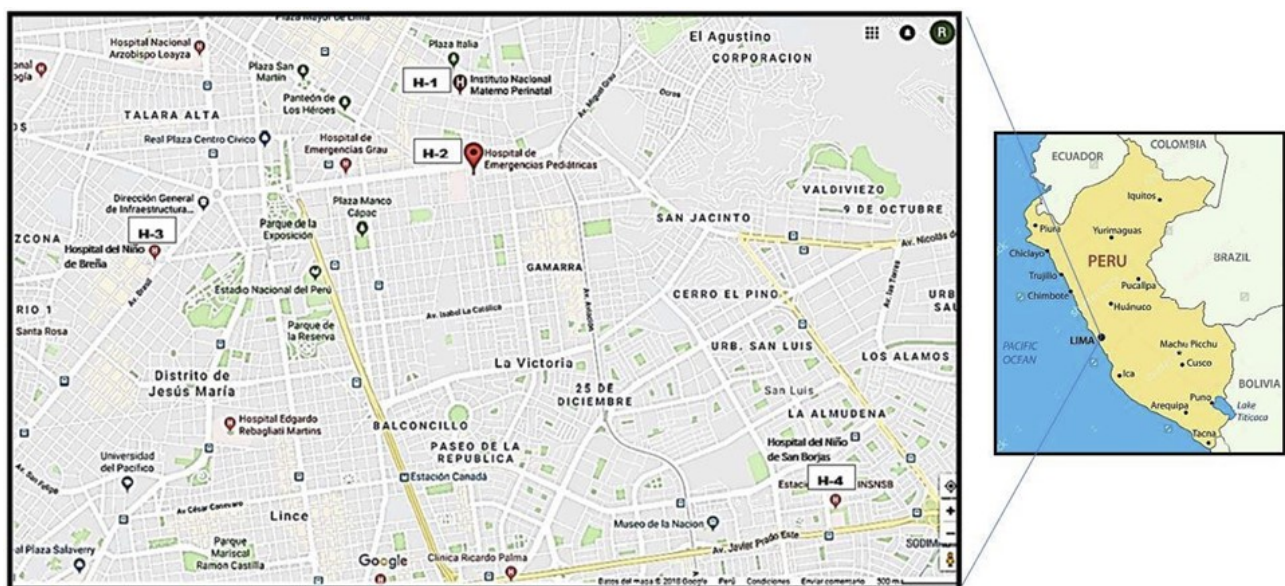


Figure 1: General Location of the Four Hospitals that are the Objects of this Study

H-1: National Maternal Perinatal Institute; H-2: Paediatric Emergencies Hospital; H-3: Breña's Children's Hospital; H-4: San Borja's Children's Hospital. Source: Prepared by the authors based on Google image, 2018.

paediatric care, segments of the hospital network most sensitive to environmental noise (Figure 1).

In three of the four hospitals (H-1, H-2 and H-3) research objectives, it is possible to recognize a significant increase in formal and informal trade in the vicinity of them, as well as the location of bus stops and signalized crossings, all of which can substantially increase noise levels.

Each of these centres provide the service of hospitalization of mothers and/or children. Therefore, their exposure to noise is longer, and that makes that the impact of noise on their health may be greater. In addition, these centres have their location very close to fifty-six important automotive transport roads, which made the hospitals potentially more vulnerable to the environmental noise of this origin type.

2.2 Equipment used

The noise measurements were made with the integrating sound level meter, model BSWA-308, Class I and its corresponding calibrator which complies with the following regulations: IEC 61672-1 2013, ANSI S1.4-1983, and ANSI S1.43: 1997. This sound level meter has a ½" MPA231T microphone for pre-polarized measurements, Class I, with a sensitivity of 40 mV/Pa, for the frequency range between 3 Hz and 20 kHz, as well as with a CA111, Class I calibrator, for 94 dB/114 dB and a frequency of 1 kHz [16].

With this equipment, measurements can be made in a range of 22 dBA to 122 dBA, for the A/B/C/Z frequencies and in the Fast/Slow/Impulse modes depending on the type of noise to be measured. The measurement period to be integrated may be up to 24 hours. This equipment has the current calibration certificate endorsed by the manufacturer. For the georeferencing of the coordinates of the points that were measured, a GPS, Garmin eTrex 30 x model with an accuracy of ± 5 m, was used.

2.3 Design of sampling networks and measurement protocol

The design process of the sampling network, the equipment to be used, and the measurement modalities and their processing have taken into account both the recommendations included in the Peruvian National Protocol for Noise Monitoring approved by Peruvian Ministerial Resolution No. 227-2013 of the Peruvian Ministry of the Environment [15]. In addition, recommendations and indications of the WHO Regional Office for Europe of 2018 included in the Environmental Noise Guidelines for the European

Region have been incorporated [17]. At each of the four selected hospitals, an exploratory network of measurement points was structured around its entire perimeter boundary in order to determine those points with the highest incidence of daytime perimeter environmental noise (Figure 2).

The measurements were carried out in a period of 22 days (with 20 days of effective measurements), where for each hospital four working days (Monday to Saturday) and one non-working days (Sunday) were characterized.

For each measurement day at one of the selected points, 16 values of the noise levels representative of each of the 16 hours of the daytime measurement period were obtained. In turn, each of these 16 values were calculated as the average of three measurements of five minutes duration.

During the noise level measurements, the equipment's microphone was always placed at a height of 1.50 meter and separated by no less than three meters from those walls or surfaces that could shield or amplify the noise.

Before and after the three measurements carried out in each sampling hour, for each measurement point, the equipment is calibrated with the corresponding acoustic calibrator for a level of 114 dBA, checking that the maximum variation is not greater than ± 1 dB.

The measurement mode used was of A-weighting, with an integration time of five minutes per recording, sufficient to be able to homogenize the vehicular flow according to the regulation times in the traffic signal network. It was measured in the Fast mode, the most suitable to characterize the noise produced by vehicular traffic, with calibrations made at the beginning and end of the measurement day. The variables measured were the following:

- Equivalent Continuous Sound Pressure Level with A-weighting (LAeq): The constant sound pressure level, expressed in A decibels, which in the same time interval, contains the same total energy as the measured sound.
- Minimum Sound Pressure Level (LAFmin): The minimum level of sound pressure recorded using the A-weighted curve (dBA) during a given measurement period in Fast mode.
- Maximum Sound Pressure Level (LAFmax): The maximum sound pressure level recorded using the A-weighted curve (dBA) during a given measurement period in Fast mode.
- Peak Values (LAPeak): It is the highest instantaneous value recorded using the A-weighted curve (dBA) in the given measurement period.

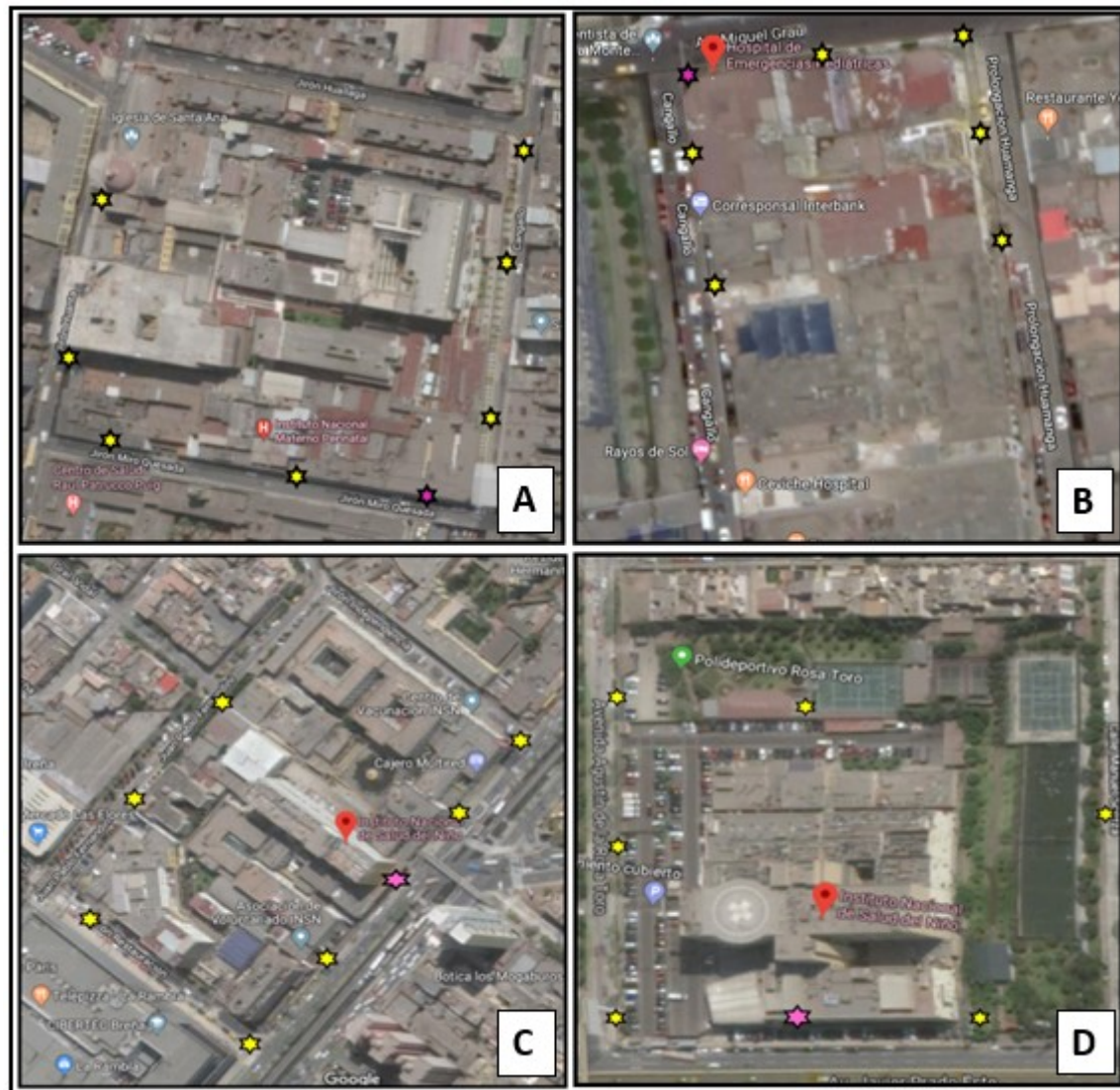


Figure 2: Exploratory Network of Measurement Points at the Four Hospitals of this Study. A) H-1: National Maternal Perinatal Institute; B) H-2: Paediatric Emergencies Hospital; C) H-3: Breña's Children's Hospital; D) H-4: San Borja's Children's Hospital
 Legend: yellow star: exploratory network point; blue star: point selected from the exploratory network because it is the point with the highest value. Source: Prepared by the authors based on Google image, 2018

Complementarily and in parallel to the noise measurement, two members of the work team counted the number of private and public transport vehicles that traveled in front of the sampling point in the period of 15 minutes. With this information, we were able to calculate the traffic intensity index referred to this period of time.

2.4 Information processing

Once the hourly values of the four variables measured and/or calculated by the sound level meter were obtained for each selected point at each of the four hospitals on

working days and non-working days (Sundays), they were entered in an Excel sheet, which allowed to elaborate tables and graphs representative of the behaviour of the environmental perimeter diurnal noise at each of the institutions and allowed for comparing the results with the other institutions and the noise of the Peruvian norms. The mean values of daytime perimeter environmental noise (LAeq) for each of the hospitals on working days and non-working days were subjected to the statistical T test in order to be able to compare their behaviour. This statistical test was used for its usefulness in comparing means for independent samples and the facilities provided for by its implementation in SPSS version 15 software.

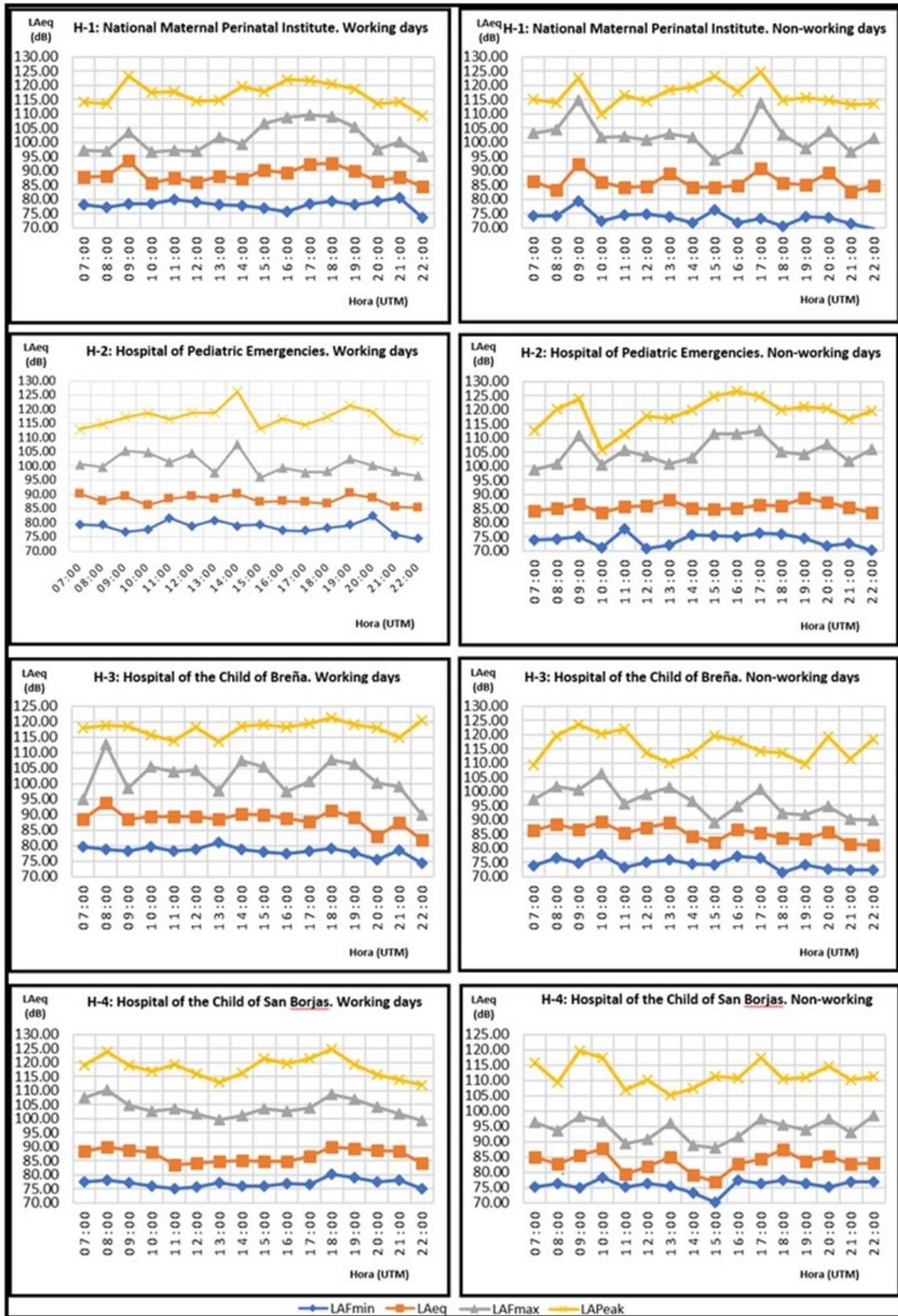


Figure 3: Behaviour of environmental noise daytime perimeter at four hospitals on working and non-working days

3 Results

Figure 3 shows the behaviour of the measurements of the environmental perimeter noise measurements made at each of the four hospitals on working and non-working days, respectively. The measurement campaign was carried out during the month of October 2018.

In general, at the four hospitals, at all the hours of measurement and both on working days and non-working days (Sunday), LAeq values are higher than the 50 dBA established by Peruvian regulations in its Standards Regulation National Environmental Quality for Noise [15] for special protection areas (those of high acoustic sensitivity, which include the Peruvian areas that require special protection against noise where health establishments, educational establishments, asylums, and orphanages are located), in the daytime (period from 07:00 hours to 22:00 hours) corresponding to the location of health centres.

On working days, two periods of maximum noise from 08:00 to 10:00 hours in the morning and from 17:00 to 19:00 hours in the afternoon coincide with the start and end of working hours. In the case of non-working days, in addition to these two maximums, it is possible to recognize a third relative maximum associated with the 13:00 hour time period, which could be associated with the displacement of a considerable percentage of cars to shopping centres and restaurants in order for people to mostly have lunch.

As can be seen in Figure 4, the average environmental perimeter noise, expressed by LAeq is lower on non-working days than on workdays with a difference of the order of 2.43 dBA to 3.55 dBA. This difference is explained by the lower density of public and private transport that circulates on non-working days (Sundays), which is reflected in Table 1 where the mean values of traffic intensity for

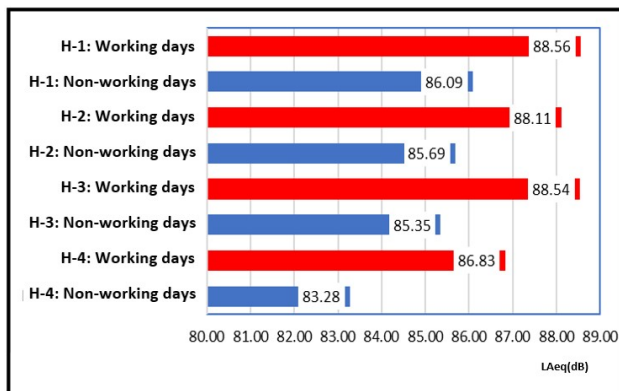


Figure 4: Behaviour of the average LAeq (dB) values according to working and non-working days at the four hospitals

Table 1: Average values of traffic intensity for the four hospitals on working and non-working days

Hospital	Average traffic intensity	
	Working days	Non-working days
H1	629	409
H2	896	564
H3	713	477
H4	1101	737

Table 2: Results of the statistical T test of comparison of the average values of each hospital on working and non-working days

Pairs of hospital	Bilateral significance	
	Working days	Non-working days
H1 - H2	0.536	0.676
H1 - H3	0.981	0.35
H1 - H4	0.027	0.002
H2 - H3	0.582	0.507
H2 - H4	0.085	0.005
H3 - H4	0.052	0.017

the four hospitals on working and non-working days are summarized. From this information, the traffic intensity index reflects a decrease 34.5% on non-working days with respect to working days, which shows the contribution of noise produced by traffic in the daytime ambient noise of these areas.

It is necessary to point out that even the minimum averages of LAFmin have values much higher than the 50 dBA established by the standard for Special Protection Areas [16].

After obtaining the results, the mean comparison T test was applied at all the hospitals considered in the study (Table 2). As can be seen, most means did not show statistically significant differences among them, with the exception of hospital H4: San Borja’s Children’s Hospital, whose results were different from the other hospitals. In this sense, H4 showed the greatest difference in relation to H1 and H2 (Sig 0.002 and 0.005, respectively) for non-working days, while the most similar means were obtained between H1 and H3, for working days.

4 Discussion

Traffic noise is the sum of the total noise produced at the observer point by all the moving vehicles on the highway [17]. According to [18], noise in urban areas is inevitable, so it is very important to know the level of it. Traf-

fic noise will continue to increase in magnitude and severity because of population growth, urbanization and the associated growth in the use of automobiles [19].

This situation is not alien in a megacity like Lima, where over 10 million inhabitants live and over 1.7 million vehicles circulate through its streets [20]. The vehicle flow increased by 3.3% in January 2018 compared to January 2017 [21]. The results obtained in the present study exceed the established values for the Peruvian Air Quality Standards in this type of area. In a special way, the four study areas qualify among the noisiest areas of Lima.

The noise is an unwanted sound, [7, 10] uncontrollable, and unpredictable sound that disturbs and annoys individuals [22], that is characterized by the frequency, periodicity intensity, and the duration of sound [23].

Undoubtedly, the situation of vehicular traffic in Lima, recent noise studies of the OEFA and the location of the four hospitals predicted thresholds of considerable noise levels. However, the results obtained in the present study far exceed the established values for Peruvian quality standards for the air in this type of area, of special character, where they are located and even qualify among the noisiest locations of Lima.

Three of the four hospitals are located on three of the avenues with the highest road congestion in Lima, which means that during the noise measurement time the traffic density was high. In this case, these hospitals are: H1 (Avenida Abancay); H3 (Avenida Brasil and 28 de Julio); and H4 (Avenida Javier Prado). Although the H2 hospital is not associated with one of these main roads, it is located at a traffic light intersection, where a significant number of vehicles converge trying to avoid traffic congestion on Abancay Avenue. This road is used as an alternative road, and, as the road is narrow, it causes significant vehicle traffic and congestion. At the same time, while ignoring traffic signals, drivers also indiscriminately honk their horns while driving through it [24].

Another factor that may be influencing high noise levels is the fact that the Peruvian vehicle fleet is 13 years old. Renewal has been taking place at a rate of 7%, when the international average is 10%. These motor vehicles (private cars, public transport vehicles, and freight vehicles), all older vehicles, are high air pollutants with gases, particulate matter, and high noise levels.

At all centres studied, San Borja's Children's Hospital presents on average 2 dB less than the rest on working days as well as non-working days (Table 1). This different behaviour has been corroborated by the statistical means T test, both on working days and non-working days, and it has a possible explanation, in the fact that, independently of the fact that Avenida Javier Prado has a high rate of vehicular traffic, its configuration consisting of multiple lanes, a concrete wall on an outer edge, and a central separator with trees, serves as a screen, absorbing much of the noise produced by traffic and reducing its impact on the perimeter of this hospital (Figure 5).

In addition, the existence of multiple lanes and a more orderly flow that, in the periphery of the remaining hospital centres, with less honking, give this environment a rather differentiated behaviour, but with values that continue to exceed Peruvian and international regulations. At the other hospitals, from the statistical point of view, the noise levels do not differ in their behaviour (Table 1).

Similar results were obtained by [25], as the main noise sources identified are due to vehicular traffic density and secondly to informal trade activities in the neighborhood of medical centres of the locality of Barrios Unidos in Bogotá.

In [26] it was demonstrated how sleep quality can affect the performance of hospital personnel and can cause human errors in prescribing and injecting medications and other therapeutic interventions. Therefore, necessary measures should be taken for reducing and controlling noise, informing personnel, changing shiftwork patterns,



Figure 5: Panoramic view of Javier Prado Avenue in front of the San Borja's Children's Hospital

and allowing for people to voluntarily choose to work shifts.

In all cases, the perimeter diurnal environmental noise levels determined at these Lima hospitals show higher values to those established by the Peruvian National Environmental Standards for Noise, for special protection areas [12], both for working days, and for non-working days. Noise that comes from the dense and disorganized traffic of Lima plays a fundamental role in this behaviour.

These high levels of perimeter environmental noise may be affecting the corresponding in-hospital environments, with the consequent impact on the recovery of patients and the health of their workers. As described in [27], where on the basis of the results of noise measurements between 59 dB and 64.9 dB as mean values in different sections of the Hospital of Babol in Iran, strategies to control and decrease sound are recommended. Personnel need to be informed and trained in order to provide for a healthier work environment for them and to improve the quality of services in the care centres.

Other studies such as [28] where a sample of 5205 workers were exposed to noise show that exposure to high levels of noise has a significant association with hypertension and hearing loss when the duration of occupational noise was greater than 10 years. Hypertension and hearing difficulties are more frequent in the group exposed to noise (more than 85 dB [A]). Also, in [29] in workers at the Sarcheshmeh Copper Complex in Kerman, Iran, the results showed that with reduced noise exposure, urinary excretion of stress hormones, especially norepinephrine, decreases significantly and workers are probably less likely to have stress-related disorders.

5 Conclusions

In summary, noise in megacities such as Lima represents an important socio-environmental problem, which is not always taken into account when building health centres or establishing the necessary regulations to preserve as far as possible adequate sound levels for areas of this type.

The results obtained are congruent with [30], since the Dutch navigation technology company TomTom, ranked Lima, Bogotá, and Mexico City as the Latin American cities that appear among the ten cities with the worst traffic in the world, according to the latest Tom Tom Traffic Index 2019 that provides information on congestion levels vehicles in 403 cities in 56 countries, Lima appears with a traffic congestion index of 57%. In the four areas where the

hospitals that were studied are located in, noise levels prevail throughout the day and during working days and non-working days well above the levels recommended by the WHO and established by the Peruvian regulations. Maximum noise peaks occur from 08:00 to 10:00 and from 17:00 to 19:00 hours.

The conformation, dimensions, and presence of plant and structural barriers on the roads can substantially reduce noise levels in the perimeter areas of hospitals.

The study was limited to only a five-day noise measurement at each hospital. A longer registration period at each of them could have provided for more solid data and for being less susceptible to short-term events, which could have affected, to some extent, the levels of sound recorded on a given day.

Finally, it is highly recommended that studies of sound levels be carried out inside the hospital, to see to what extent the high sound levels existing in the outer perimeter of the four hospitals studied contribute to the increase in sound levels in the different units of these centres. These measurements must be carried out both by using the sound level meter to characterize the different areas, as well as by personalized dosimetry by areas and different types of work.

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Conflict of Interests: The authors declare no conflict of interest regarding the publication of this paper.

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