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Environmental Pollution

Evaluation of urban pollution by noise emissions registered with a sound level meter and sensor nodes

Evaluación de la contaminación urbana por emisiones sonoras registradas con sonómetro y nodos sensores

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Abstract

The increase in noise emissions is associated with an increase in the population, with anthropic activities, and it is in urban centers where a series of effects on both the population and the environment occur. The present study covered the evaluation of the noise behavior in the city of Cuenca during 2019, for which monitoring was carried out in 31 points distributed in the city based on the average daily traffic, the ordinance of use and occupation of the land and the dynamics of the population. The national environmental standard TULSMA (Unified Text of Secondary Legislation of the Ministry of the Environment) was taken as a reference. To establish the comparison of the data collected with a (low-cost, noise level) sensor and a sound level meter, measurements were made in 6 monitoring stations established on the basis of noise complaints made by citizens to the autonomous decentralized municipal government of Cuenca (GAD) and the security conditions to place for the placement of the equipment. The results showed that noise, in the city of Cuenca during 2019, noise is above the TULSMA environmental standard in Zone EQ1 (100% of the measurements), Zone R1 (96% of the measurements), Zone CM (100% of the measurements) and in Zone ID3 / ID4 (72% of the measurements). There was a high correlation coefficient (r = 0.8) and determination coefficient (R^2 >0.6), between the data collected with the sensor and the sound level meter. It is worth highlighting the use of the calibrated sound level meter when making sound measurements with various instruments, as it allows the data to be verified and validated.

Keywords: noise, sound level meter, sensor nodes, TULSMA.

Resumen

El incremento de las emisiones sonoras se asocia a la actividad antrópica y es el centro urbano en donde se presentan afectaciones a la población y al entorno. El presente estudio tuvo dos componentes, el primero abarcó la evaluación del comportamiento sonoro en el área urbana de Cuenca-2019, en donde se realizaron monitoreos en 31 puntos distribuidos en la ciudad en función del tráfico promedio diario, uso del suelo y dinámicas de la población; se tomó como referencia la norma ambiental nacional TULSMA (Texto unificado de legislación secundaria del Ministerio del Ambiente). Los resultados mostraron que el ruido sobrepasa los límites de la norma en el 100 % de las mediciones realizadas en la zona de equipamientos de servicios sociales (EQ1), 96 % de las mediciones en la zona residencial (R1), 100 % de las mediciones en la zona comercial (CM) y en el 72 % de las mediciones de la zona industrial de mediano y alto impacto (ID3/ID4). En el segundo componente se compararon los datos levantados de manera simultánea con sensor y sonómetro, en seis nuevas estaciones de monitoreo establecidas sobre la base de las denuncias de ruido realizadas por la ciudadanía a la autoridad municipal de Cuenca y las condiciones de seguridad para la colocación de los equipos. Se obtuvo un alto coeficiente de correlación (r = 0,8) y de determinación (R^2>0,6), entre los datos levantados con sensor y sonómetro. Se resalta el uso del sonómetro calibrado cuando se realizan mediciones sonoras con diversos instrumentos, ya que permite verificar y validar los datos.

Palabras clave: ruido, sonómetro, nodos sensores, TULSMA

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1 Introduction

Sound is defined as a sound wave capable of producing the sensation of sound; and loudness is the subjective sensation generated by pressure variation in the ear (Laforga, 2000). For physics, "it is a sensation perceived by the ear, due to pressure differences produced by the vibration of a body" (Robles and Arias, 2015, p. 10), while noise is associated with annoying, unwanted sounds (García and Garrido, 2003; Robles and Arias, 2015), or "any sound that disturbs human beings and the development of their activities" (Rodríguez, 2015, p. 3).

Since their appearance on the planet, living beings have been receptors of a variety of sounds coming from the environment; however, environmental sound has been associated with anthropic activity. It is currently considered undesirable because it affects the natural balance, harms the population and is presented as an important source of pollution in cities (Alfie and Salinas, 2017) and a public health problem (Fiedler and Zannin, 2015).

The sources of noise range from the use of vehicles at high speeds, without revision or maintenance, raising the voice, among others, which come from the usual actions of the population (García and Garrido, 2003), including factors such as age, stress level or aspects such as air quality can affect positively or negatively the perception of sound and influence the soundscape of a territory (Moraga et al., 2017).

Urban areas present a continuous population growth that propitiates the entry of population for studies, management, work or residence and leads to an abandonment of the peripheries causing imbalances in the territory (Gómez and Vallarino, 2010), resulting in alterations to the urban environment such as vehicular congestion that emits gases, particulate matter and noise into the atmosphere, causing loss of environmental quality of the urban center.

It is necessary to establish the impact of noise in terms of the effects it can cause to society, either physiologically or psychosociologically; for this reason, noise is studied by universities, public and private entities worldwide. According to Romo Orozco and Gómez Sánchez (2013), high noise levels can affect the auditory organ and low levels can affect psychosomatic health.

As expressed by Burneo (2007a), the continuous and constant exposure to excessive or high levels of noise slowly induces the irreversible loss of hearing (Daiber et al., 2019), increases cardio-metabolic diseases, arrhythmia, diabetes mellitus and, there are cases of stress that can trigger vasoconstriction, heart rate variability and coagulation depending on the emotional conditions of the people exposed (Daiber et al., 2019).

Grass et al. (2017, p. 5) expresses: "When exposed to high levels of noise for a prolonged period of time, the stomach may secrete an acid substance and a quantity of adrenal hormones; these are the first alarm symptoms of acute stress; there may also be difficulty in concentrating, which triggers a decrease in the level of performance and increases the level of anxiety in the professional by feeling uncommunicative with his environment, in addition to irritability, sleep disorder, fatigue and depression", and critical groups such as infants, children, the elderly, the sick and pregnant women are more prone to this (Burneo, 2007b).

The global burden of disease has changed as a consequence of industrialization and modernization, because it incorporates a risk factor such as noise that generates chronic diseases (Daiber et al., 2019); not only physical but also psychological such as stress, interference with speech communication, loss of performance, alterations that grow when the sound increases, affecting the quality of life (Basner et al., 2014; Nazneen et al., 2020).

The sound level is increasing, and it necessary to delimit it, regulate it and combat it with policies and legislation (García and Garrido, 2003). It is not a habitual activity because it has been considered as a common fact product of everyday life, giving little importance to its effects (Bañuelos Castañeda, 2005). For society, pollution is the negative effects on factors such as water, soil, air, while noise is qualified as "not very serious" (Zamorano et al., 2015, p. 2).

Sound was initially quantified with music in a qualitative way, i.e., loud, high, etc., without scientific accuracy, depending on the auditory acuity of the person who perceives it (Long, 2006). After multiple experimental studies Fletcher Munson (1933), Robinson and Dadson (1956), elaborated the curves with loudness levels based on human judgments about a perceived tone, compared to a reference one (Long, 2006); but they could not be used with an analog sound meter, so electrical weighting filters have been developed, which approximate the Fletcher Munson curves, named with letters of the alphabet A, B, C (Long, 2006).

With the aim of showing the population information related to noise, the University of Azuay (UDA) monitors these emissions in Cuenca since 2009 with certified sound level meter on an annual basis, and since 2018 with sensor nodes in real time on a continuous basis, contributing to compliance with Art. 14 of the Constitution of the Republic of Ecuador which stipulates: "The right of the population to live in a healthy and ecologically balanced environment, which guarantees sustainability and good living, sumak kausay...." (Asamblea Constituyente, 2008, p. 13).

The city under study is home to approximately 66 % of the canton's population (INEC, 2010), with a total of 330,000 inhabitants; resulting in areas with widespread noise pollution, a phenomenon that requires attention (García and Garrido, 2003). Along with population growth, technological evolution allows for better development of cities, forming what are called "smart cities" (UNRN, 2010), a concept related to the communication infrastructure for collecting information and distributing it through networks.

Information and communication technologies (ICTs) have improved the quality of life of the population, reducing management and mobilization time and contributing to the reduction of emissions and environmental pollution (Lin et al., 2011).

Wireless sensor networks consist of a data acquisition network and a data distribution network, controlled and monitored by a management center (Lewis, 2004); this network consists of data generator and relay nodes, a microprocessor and a transceiver (Akyildiz and Vuran, 2010). Its applicability is wide, the data captured can be environmental variables such as meteorological data, sound emissions, water quality, environmental monitoring, with the ability to transmit in real time (Quiñones Cuenca et al., 2017).

Acoustic emissions are monitored in cities of Ecuador; noise levels from fixed and mobile sources have been studied in Guayaquil in the framework of the design of an air quality monitoring network, determining the equivalent sound pressure (NPSeq) in decibels dB (IDYC, 2016). Quito and the Historic Center of Cuenca have used tools such as Cadna A software and the prediction-propagation model "HARMONOISE P2P" respectively, to elaborate maps that represent the noise in areas of the city (Bravo Moncayo, 2019; Armijos-Arcos, 2018).

The research carried out included the evaluation of noise behavior in Cuenca in 2019 in 31 pre-established points, data collected with a sound level meter. Additionally, simultaneous measurements were made with sound level meter and noise sensors in six new monitoring points in order to establish the accuracy degree in data collection; the values allowed the comparative analysis.

2 Materials and methods

The project was developed in the urban area of Cuenca, province of Azuay, located at 2550 m.a.s.l., with 331 888 inhabitants (INEC, 2010), in an area of 79.59 km^2.

2.1 Equipment

The information was collected with a SOUNDPRO DL-2-1/3 SLM model sound level meter, series BCQ120001, Class 1 integrator and duly certified, which allows obtaining the equivalent average level automatically on the basis of all the samples recorded in the determined period (15 minutes). The data collected for each monitoring point was the equivalent sound level (Leq) with A/C scale, recommended for environmental noise monitoring (Long, 2006). The (Leq) measures "the constant level of noise with the same energy content as the acoustic variation of the calculated sound signal" (Aagesen, 2002, p. 57).

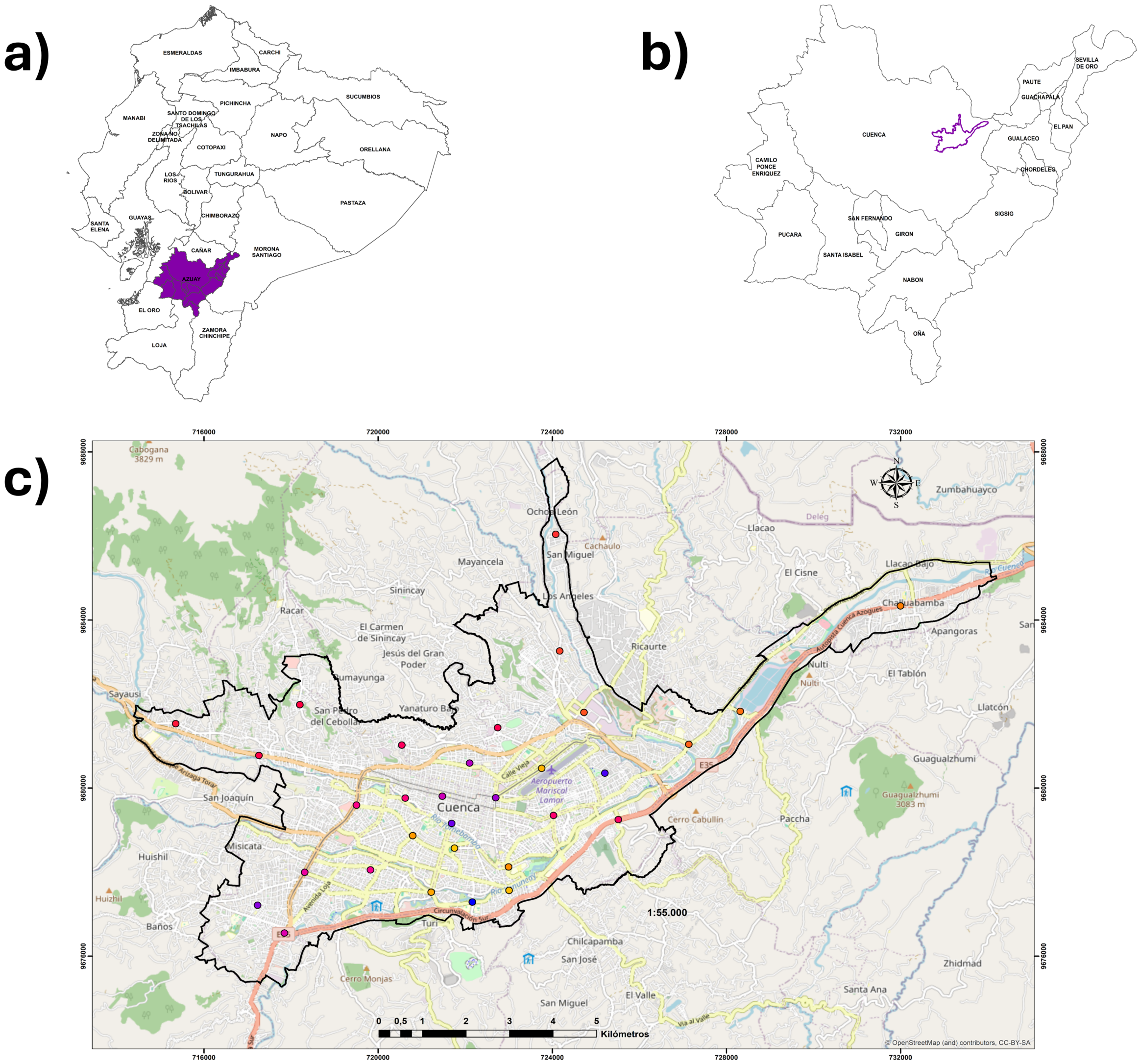

Figure 1. Maps of Project location: a) Location of the Azuay province. b) Location of the city of Cuenca. c) Project area. Preparation based on information from INEC, 2010 and the Institute of Sectional Regime Studies of Ecuador IERSE-UDA, 2019.

The technology used for noise sensors is based on the internet of things model, and is constituted by a set of wireless sensor nodes that form a network; these devices have the capacity of processing, storing and communicating, and it is equipped with a battery that provides them with energy (Salgado and Carranco, 2017).

The referential sensor nodes are called "Waspmote plug sense", which consist of a waterproof packaging (IP65) with sockets for sensor connection, solar panel, antenna and a terminal for node programming. The model used is: *Smart Cities PRO (SC_ NODE)* (Salgado and Carranco, 2017).

This research is empirical with a quantitative approach and the data were collected between March and April, 2019. The research started collecting the data in situ with both sound level meter and sensor. The information collected was compared with the standards established in the text from the Ministry of the Environment (Ministerio de Ambiente, 2019), then the data obtained with sensor and sound level meter were correlated.

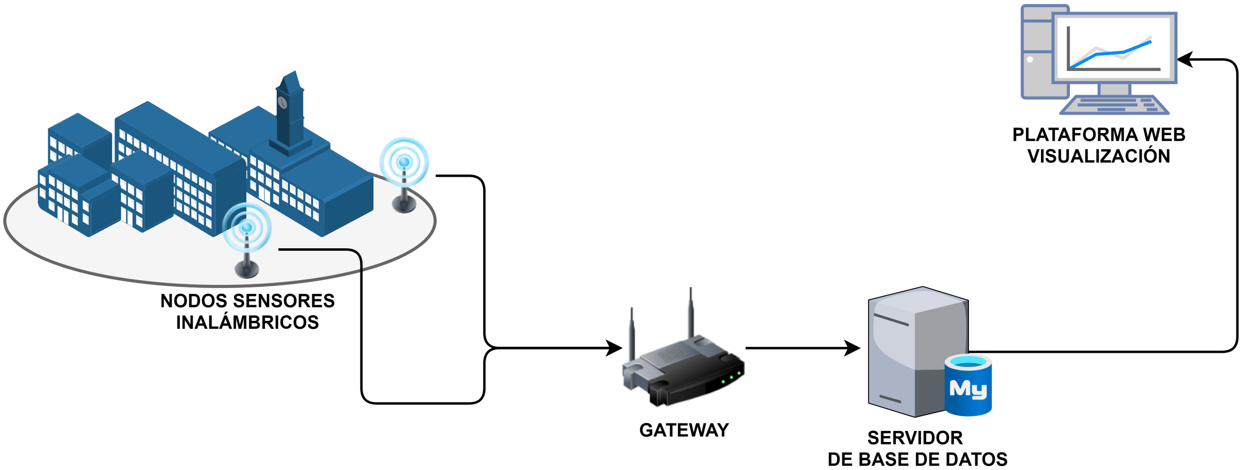

Figure 2. Schematic of the operation of the wireless sensor network and data transmission. Figure made by Darío Espinoza.

2.2 Sound level meter monitoring

There is a network of 31 monitoring points (Figure 3); three criteria were considered for their location: traffic density, land use and occupation, and population dynamics. Measurements were taken at six times, corresponding to the peak hours of vehicular flow in the city of Cuenca: 7:01 a.m., 1:00 p.m. and 6:00 p.m., and off-peak hours 10:00 a.m. and 3:00 p.m.; in addition, the night hours of 9:01 p.m. were included.

These schedules were established based on the study conducted by the GADMCC, which determined the peak and off-peak hours of vehicles from the city center (GAD Cuenca, 2007). The monitoring period per point was 15 minutes in each schedule, complying with the provisions of Annex V of the TULSMA, which recommends a monitoring period of at least 10 minutes (Ministerio de Ambiente, 2019).

2.3 Monitoring with sensor nodes

Six monitoring points were established (Figure 4) and their location was based on noise complaints received in the Municipality of Cuenca, areas reported as noise generators and logistical conditions such as power requirements, video cameras and equipment security.

The information from the sensor nodes is captured continuously and in real time since October 2018; the data are presented in periods of 12.25 min on the UDA website. The information reported between March 18 and April 15, 2019 was used, and the sensor schedule was unified with those of the sound level meter, i.e., the equivalent sound level (Leq) was determined for 7h01, 10h00, 13h00, 15h00, 18h00 and 21h01.

This calculation was performed with the data reported by the sensor for one hour. The values obtained are the result of the automatic average of all the samples captured during one hour. The weighting scale of the sensors is (A) and the averages in this period were arithmetic. The data obtained with a sound level meter were measured for a period of 15 minutes in each hour at each monitoring point.

2.4 Assessment of noise in the city

To establish the sound behavior in 2019, Annex 5 of the Unified Text of Secondary Legislation of the Ministry of Environment (TULSMA, 2019) of Table 2 was used as a reference. The 31 monitoring points with sound level meters are described in Table 3. While, the six points where simultaneous monitoring was performed are described in Table 4.

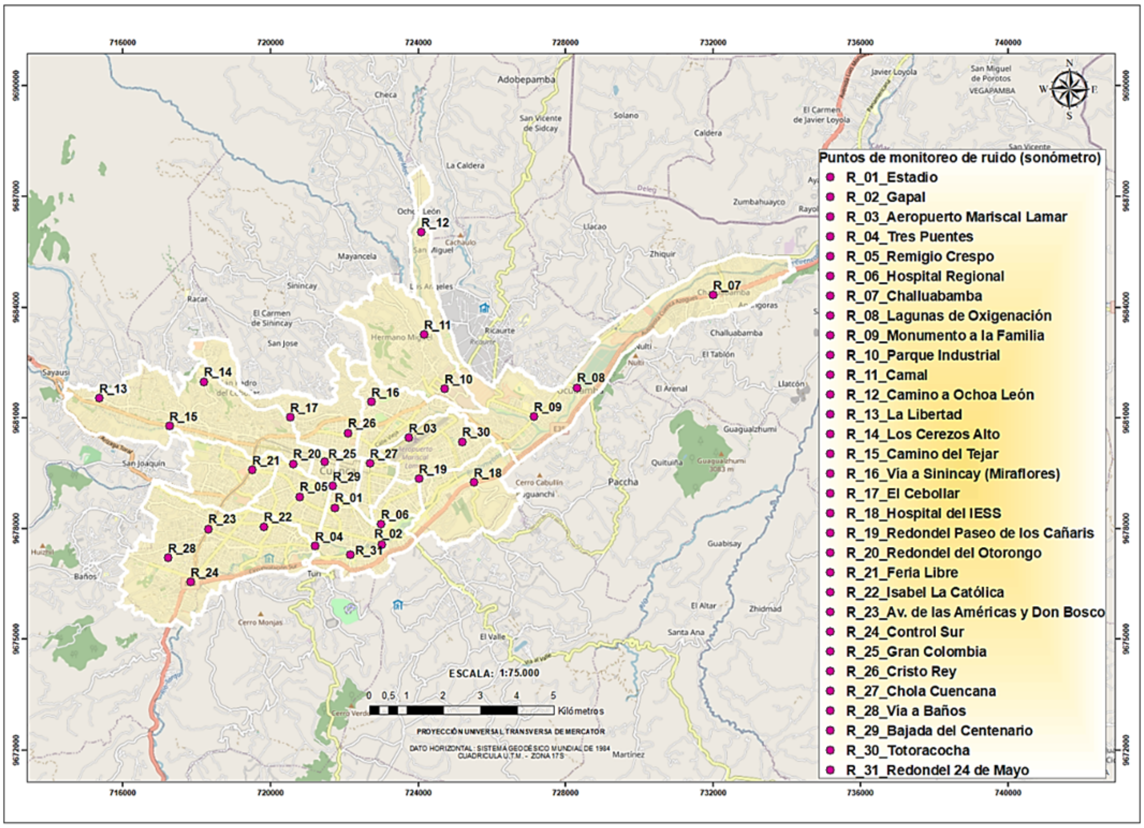

Figure 3. Location of sound level meter monitoring sites.

Table 1. Location of noise sensors in 2019.

Code	Area	Primary Street	Secondary Street
SCP-04	Escalinata Juana de Oro	Calle Larga	Escalinata
SCP-05	Presidente Córdova	Presidente Córdova	Vargas Machuca
SCP-06	Remigio Crespo	Remigio Crespo	Agustín Cueva
SCP-07	Estadio Serrano Aguilar	Av. del Estadio	Av. Manuel J. Calle
SCP-08	Mercado El Arenal	Av. de las Américas	Av. Remigio Crespo
SCP-09	Parque Industrial	Paseo Río Machángara	Av. Octavio Chacón Moscoso

3 Results and discussion

3.1 Noise emissions in Cuenca with sound level meter 2019

The analysis of the data collected with sound level meter and evaluated based on the TULSMA (2019) are represented in the Figure 5. Furthermore, the noise data obtained for all the study zones are above the limits established in the environmental standard -TULSMA, in all sampling hours (See Table 2). In the social services equipment zone (EQ1), the means at all times are between 68 dB and 72.3 dB. At 7:00 am, 1:00 pm, 3:00 pm and 6:00 pm, most of the data are above 70 dB.

The residential zone (R1) has the highest monitoring number, with mean values at different times ranging from 68.2 dB to 72.4 dB. The lowest value was at 3:00 p.m. with 54.3 dB. The mean values in the commercial zone (CM) are between 68.2 dB and 72.4 dB and at 7:01 am, 1:00 pm, 6:00 pm and 9:01 pm, the data obtained are mostly above the mean and at 10:00 am and 3:00 pm most are below the mean.

Table 2. Permissible noise limits -TULSMA, (2019).

Land Use	Lkeq (dB)	
	Daytime period 07:01 a 21:00h	Night period 21:01 a 07:00h
R1	55	45
EQ1	55	45
CM	60	50
ID3 / ID4	70	65

In the industrial zone (ID3/ID4), the mean ranges from 64.7 dB to 70.4 dB, in the hours 7h01, 10h00, 13h00, 18h00 and 21h01; the data obtained are mostly above the mean; there is only one value of 64.3 dB in the 21h01 schedule that is below the TULSMA -2019 standard; all the remaining values in the different schedules are above the mentioned standard.

The noise values in the city of Cuenca for the year 2019 are above the established legislation in all monitored schedules and in all land use and occupancy zones. The surveyed data that are over the TULSMA standard are: Zone EQ1 (100 %), Zone R1 (96 %), Zone CM (100 %) and Zone ID3/ID4 (72 %) of the total measurements taken. The WHO indicates that the noise values for vehicular traffic are around 70 dB. Therefore, since the monitoring in Cuenca was carried out at critical points on the roads with the most vehicular traffic, the data obtained are in accordance with the WHO (Berlung et al., 1999).

3.2 Noise emissions with sensor nodes vs. sound level meter

With the aim of conducting a comparison, measurements with sensor and sound meter were done in the six points indicated in Figure 4; and the results are detailed in Table 5.

Table 3. Sound level meter monitoring points by land use.

No.	Measured point (area)	Land use (TULSMA 2019)
R_02	Gapal	
R_04	Tres Puentes	
R_07	Challuabamba	
R_08	Lagunas de oxigenación	
R_09	Monumento a la Familia	Residential
R_12	Camino a Ochoa León	
R_13	La Libertad	
R_15	Camino al Tejar	
R_16	Vía a Sinincay (Miraflores)	
R_17	El Cebollar	
R_26	Cristo Rey	
R_28	Vía a Baños	
R_30	Totoracocha	
R_01	Estadio	
R_03	Aeropuerto Mariscal Lamar	
R_05	Remigio Crespo	
R_19	Redondel Paseo de los Cañaris	Commercial
R_21	Feria Libre	
R_23	Av. de las Américas y Don Bosco	
R_24	Control Sur	
R_25	Gran Colombia	
R_27	Chola Cuencana	
R_29	Bajada del Centenario	
R_06	Hospital Regional	
R_18	Hospital del IESS	Social services facilities
R_20	Redondel del Otorongo	
R_22	Isabel La Católica	
R-31	Redondel 24 de Mayo	
R_10	Parque Industrial	
R_11	Camal	Industrial
R_14	Los Cerezos Alto	

Figure 6 shows the differences presented between measurements made with sensor and sound level meter for each of the measurement points. At the "Calle Larga" station, the sound measurement difference between the sound level meter and the sensor is between 2.5 dB and 3 dB. At the "Calle Presidente Córdova" station, the difference of measured value with sensor and sound level meter varies between 2.9 dB and 5.1 dB. The greatest differences are found at the "Remigio Crespo Avenue" station, which vary between 1.3 dB and 9 dB. At the station "Sector Estadio Serrano Aguilar", the variations range between 0.0 dB and 2.9 dB, which occur between 15h00 and 21h00; while the differences are minimal at the other measurement times. The data collected at "El Arenal Market Sector" station show a variation of less than 1 dB. Noise emissions at "Parque Industrial" station vary between 3 dB and 6.3 dB.

Table 4. Monitoring points with sensor and sound level meter by land use.

No.	Measured point (area)	Land use (TULSMA, 2019)
SCP-04	Calle Larga (Escalinata Juana de Oro)	Commercial
SCP-05	Presidente Córdova	
SCP-06	Remigio Crespo	
SCP-07	Estadio Serrano Aguilar	
SCP-08	Mercado El Arenal	
SCP-09	Parque Industrial	Industrial

The correlation was mainly analyzed from the data obtained with the sensor vs. sound level meter. Pearson's correlation coefficient (r) and Spearman's correlation coefficient (rho) were obtained, in addition to their $p-$values of significance, where the most representative data are highlighted in Table 6. The r coefficient in the monitoring sites: Calle Larga, Presidente Córdova, El Arenal and the Industrial Park, present values between 0.8 and 0.99, which show a high correlation between the data obtained with the sensor and the sound level meter; in the sector of the Serrano Aguilar Stadium, the rho coefficient applies (due to the non-normality of the data) with a value of 0.81. Remigio Crespo street presents erroneous values, indicating that there is some problem with this sensor node. In general, the statistical indicators show that there is variability in the data in areas such as the Industrial Park and the Serrano Aguilar Stadium, while Remigio Crespo Street showed errors in the measurement, indicating the possibility of failures when using sensor nodes.

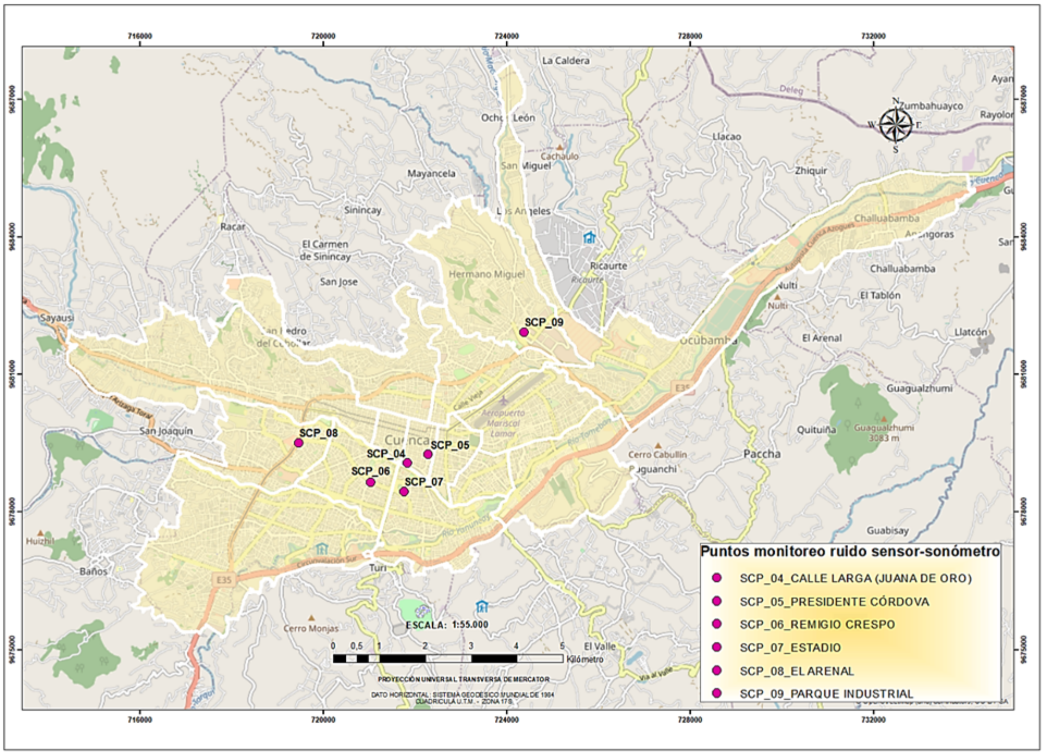

Figure 4. Location of sensor monitoring sites-2019.

As can be seen in this section, the data collected at the six monitoring points with sensor, sites where data were simultaneously collected with the sound level meter were analyzed. The noise data obtained with the two devices are above the limits established in the environmental standard (Ministerio de Ambiente, 2019).

Additionally, it can be observed that there are differences between the data collected at all monitoring points. Among the causes of the difference, it can be mentioned: The weighting filter in which the sensor measures is "A", while with the sound level meter it is A/C; the optimal measurement range of the sensor is "50 dB- 100 dB". The sound level meter, being simultaneously configured in A/C weighting, has a greater measurement range that allows it to perceive low and high frequencies (Salgado and Carranco, 2017).

Another element analyzed is the height of data collection. The sensors were placed on the poles where the necessary logistical conditions were met; but the height of placement depends on the location where the ECU 911 surveillance cameras are located.

The approximate height was 4 m above ground level and each sensor was located at a different height, making it impossible to establish a correlation that would allow a generalization of behavior. According to the results obtained, the values captured by the sensors are lower than those of the sound level meter, due to the difference in the height of data capture, since the sound level meter monitors noise at 1.80 m above the floor level and the sensors are above 4 m above the floor level.

There are other experiences such as in Quito, which has a noise map for the day and another one for the night (Bravo Moncayo, 2019). The city has been divided by sectors (32) for collecting the data, identifying information such as: sector name, noise emissions (dB), potential and highly annoying population. To determine noise pollution, CadnaA (Computer Aided Noise Abatement) software was used, which models noise as a function of vehicular traffic and road characteristics such as lane width, road surface, traffic speed, IMD, etc. They randomly perform data validation with the use of a calibrated sound level meter (Bravo Moncayo, 2019).

The results show noise levels between 61.90 dB (El Condado) to 72.70 dB (Historic Center). During the day and at night the values decrease from 54.80 dB (El Condado) to 67.40 dB (La Libertad sector) (Bravo Moncayo, 2019).

Table 5. Noise emissions with sensor and sound level meter.

Schedule	07:01	10:00	13:00	15:00	18:00	21:01
Sensor noise						
SCP-04	68.8	68.2	68.7	68.0	68.5	65.0
SCP-05	72.6	71.9	73.3	71.7	72.0	66.2
SCP-06	63.5	66.5	65.9	65.6	66.0	61.3
SCP-07	66.9	68.0	67.5	68.0	67.9	62.9
SCP-08	69.9	69.7	69.4	70.0	70.2	67.1
SCP-09	73.1	72.3	72.3	72.8	71.8	67.6
Noise sound level meter						
SCP-04	71.8	70.5	71.1	70.7	70.9	67.4
SCP-05	76.1	75.8	76.2	75.9	75	71.3
SCP-06	70.4	67.8	70.8	70.7	69.3	70.3
SCP-07	67.1	68	67.4	68.3	70	65.8
SCP-08	70.8	70.3	69.6	69.5	70.3	67
SCP-09	76.1	76.5	78.6	76.2	75	72.6

Noise in the Historic Center of Cuenca has been studied by the Salesian Polytechnic University (Armijos, 2018), specifically in an area of 250 m, around a monitoring point located in Gran Colombia and Tarqui streets. Through the use of the prediction-propagation model "HARMONOISE P2P" a map of the noise generated by vehicular traffic is elaborated, using a sound level meter to validate the data.

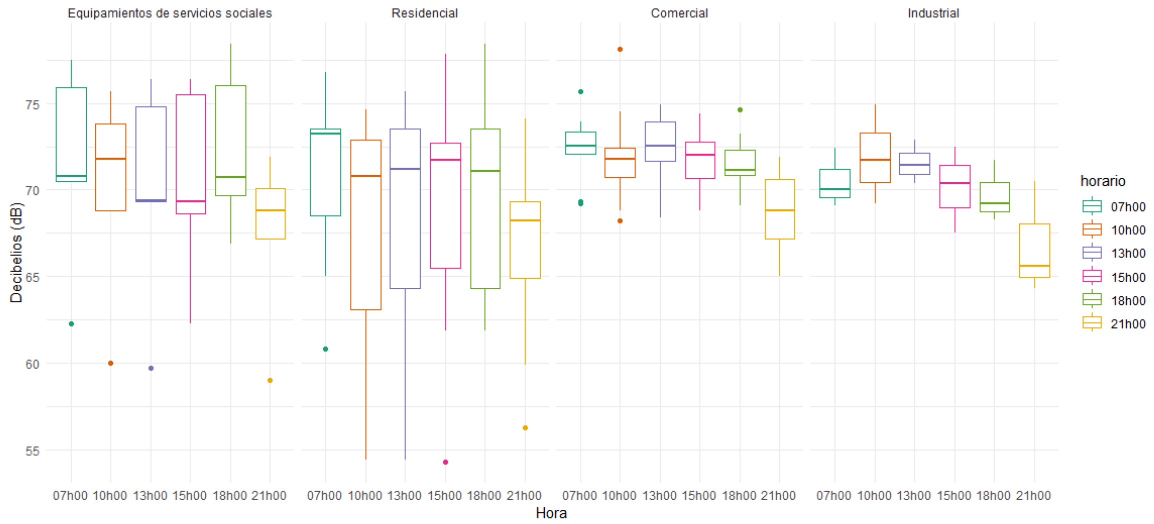

Figure 5. Measurement Graph of sound level– Classified by land use of Cuenca, 2019.

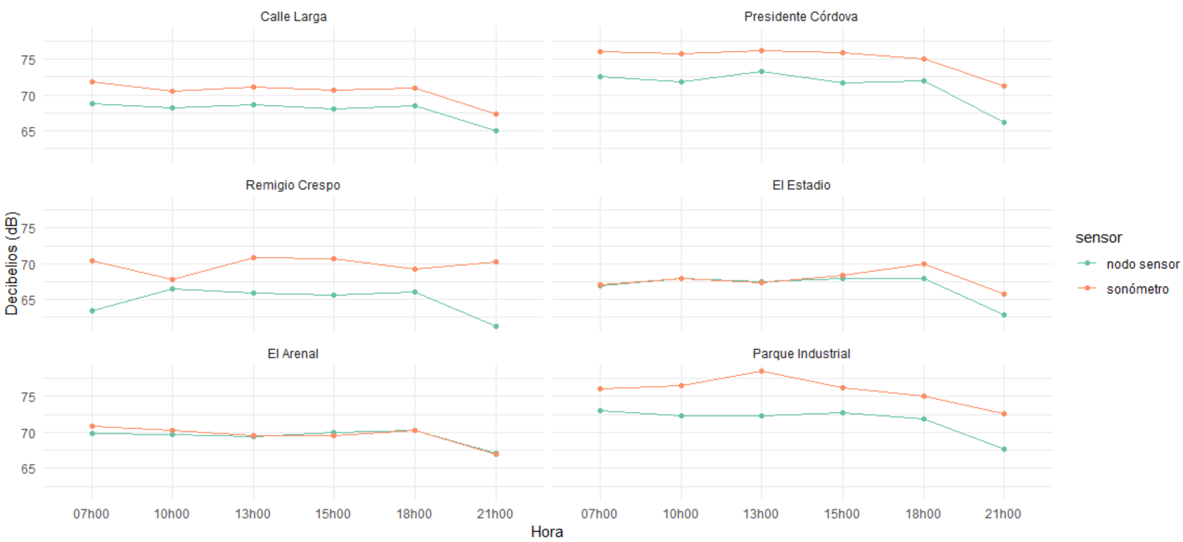

Figure 6. Comparison of the emissions made with sensor and sound level meter.

An average of 68.58 dB is obtained with the prediction model. The value is 71.84 dB with the sound level meter, and the difference is -3.26 dB; hence, it is concluded that the propagation model is adequate (Armijos-Arcos, 2018). Guayaquil monitors noise using a sound level meter that monitors 52 pre-established points based on vehicle traffic, in periods of 12 min. The values obtained are above 70 dB (IDYC, 2016).

Table 6. Correlation of the data.

Performance indexes		Comparison of Sound Level Meter vs. sensor					
Name	**Symbol**	**Calle Larga**	**Presidente Córdova**	**Remigio Crespo**	**Estadio Serrano Aguilar**	**El Arenal**	**Parque Industrial**
Mean square error	RMSE	2.54	3.84	5.65	1.47	0.5	4.34
Standard deviation	rSD	0.93	1.36	1.74	1.42	0.85	1.03
Pearson correlation coefficient (-1<= r<=1)	r	**0.99 (value-p = 0.0003)**	**0.98 (value-p = 0.0008)**	-0.41 (value-p = 0.6034)	0.77 (value-p = 0.0724)	**0.93 (value-p = 0.0064)**	**0.8 (value-p = 0.0571)**
Spearman's correlation coefficient (-1<= rho<=1)	rho	0.94 (value-p = 0.0167)	0.77 (value-p = 0.1028)	-0.43 (value-p = 0.4194)	**0.81 (value-p = 0.04989)**	0.46 (value-p = 0. 3542)	0.46 (value-p = 0.3542)
Determination coefficient (0 <= R2 <= 1)	R2	0.97	0.95	0.17	0.6	0.87	0.64
Regression coefficient (0 <= bR2 <= 1)	bR2	0.94	0.91	0.15	0.59	0.87	0.6

4 Conclusions

The proposed methodology allowed to have a set of noise monitoring points distributed in the city and taking as a criterion the density of vehicular traffic. The data collected present greater acoustic intensity, being the most unfavorable for the population. The period of sound emissions survey for 15 minutes allowed to comply with the sampling method in force in the law (Ministerio de Ambiente, 2019) and to establish a diagnosis.

The emissions measured with a sound level meter in the 31 points are above the environmental standard; this is explained because the monitoring was performed in places with high intensity of vehicular traffic and not inside the buildings.The data obtained in six simultaneous monitoring areas with sensor and sound level meter do not comply with the TULSMA. In this case, the points were chosen based on complaints of excessive and periodic noise nuisance.

Other experiences in cities such as Quito and Guayaquil show emission results similar to those obtained in Cuenca and exceed the limits of the legal standard. It is important to highlight the use of the calibrated sound level meter because it is a reference for measurements made with other devices or tools, whether simulation, prediction or sensor nodes that have required random validation.

The data collected with sensor and sound level meter simultaneously in the following sectors: Calle Larga, Presidente Córdova, Estadio Serrano Aguilar, Mercado El Arenal and Parque Industrial have a correlation between (0.81 to 0.99), and - 0.41 were obtained in the sector Av. Remigio Crespo Toral due to an error in the measurement of the sensor node, making it difficult to determine a correction factor between the sensor and sound level meter for this point. However, it is important to present this result since it shows a risk that can occur when using sensor nodes. Additionally, determination coefficients (R2) and regression coefficients (bR2) were calculated, whose results ratify the alteration of the data captured with the sensor (SCP- 06). For subsequent monitoring, the existence of anomalies in the equipment or factors such as the presence of magnetic fields or an electric transformer that disturbs the normal operation of the sensor should be checked.

For analyzing the noise data, the continuous equivalent level (Leq) captured in the different schedules was used. The (Leq) programmed from the sensor was arithmetic and in band (A), and the average is logarithmic and in band (A/C), from the sound level meter factors that influenced the results obtained.

Author Contribution

J.M.G.: Conceptualization, formal analysis, methodology, project administration, supervision, visualization, writing-original draft, writing-review and editing; O.D.I.:Conceptualization, methodology, validation; I.V.G.: Data curation, formal analysis, research; D.E.S.: Data curation, Software, research; F.S.C.: Formal analysis.

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