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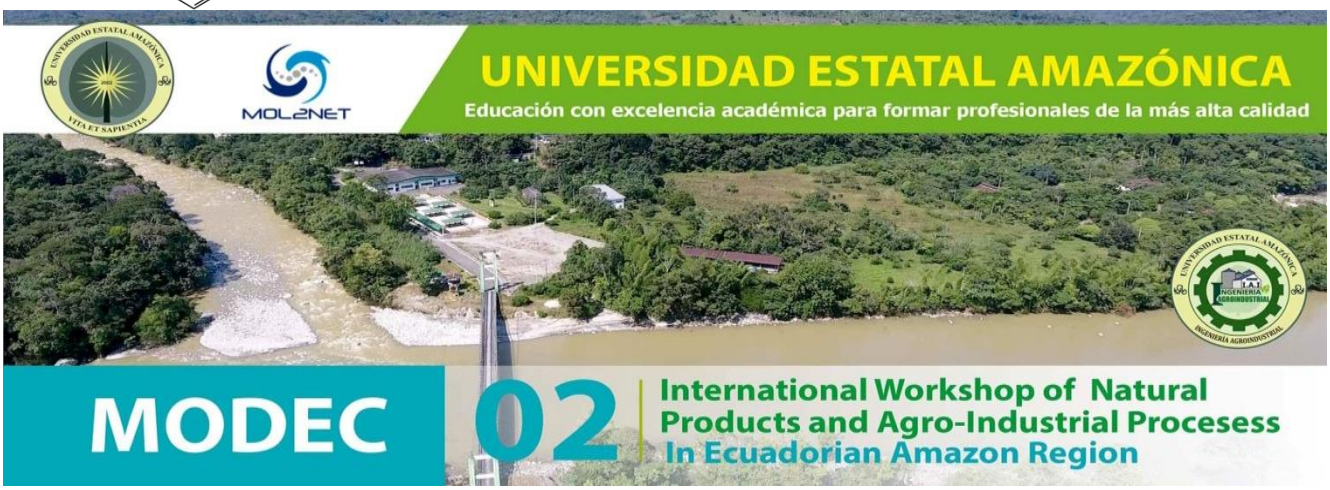

Evaluation of the noise pollution of the Cevallos avenue, Ambato city, Ecuador, for the determination of critical points of affectation in the place, and to provide information that allows the generation of preventive and corrective measures to the problem

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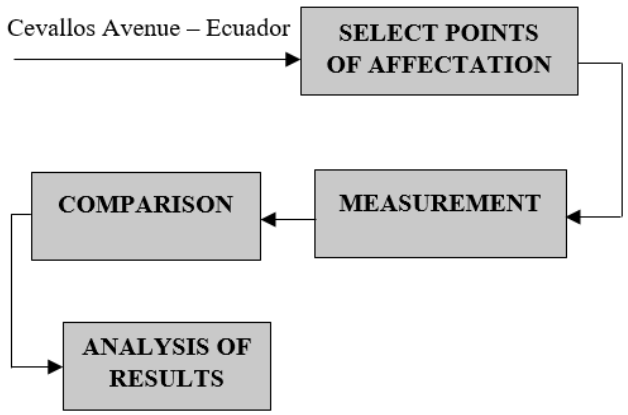
Graphical Abstract *(mandatory)*



Abstract.

In Latin American cities, economic activities generate environmental contamination directly or indirectly, one of the most important being noise pollution. The present study focuses on evaluating the environmental noise of Cevallos Avenue in Ambato City, taking into account that this location presents the highest congestion of the city, both vehicular and pedestrian, and is one of the most important places in the city due to the commercial activities and entertainment. Ambato is the tenth most populous city in Ecuador, with 175,000 inhabitants, and is located in the center of the inter-Andean region. Monitoring of the sound pressure level at four critical points of affectation (PCA) of the avenue is carried out, where measurements of noise emitting sources (FER), stationary and mobile, are made. This is carried out through four samplings at each point, spread over two days, and lasting for fifteen minutes each, following the methodology presented in Annex 5 of Book VI of the Unified Text of Secondary Legislation of the Ministry of the Environment (TULSMA, for its acronym in Spanish), regulations applied in Ecuador. The

resulting values are compared with other works carried out in the study area, and it is determined that 95% does not comply with the maximum permissible limits presented in the current Ecuadorian environmental regulations, both in day and night periods.
Keywords: monitoring, critical point of affectation, emission sources of noise, maximum permissible limits.

Introduction.

At Latin American scale, control and argumentation against environmental noise in cities hardly reach a priority position in environmental agencies in the countries. As a consequence, its monitoring is not constant in the majority of Latin American cities, or at least not as a part of official programs (Medina and González, 2016). In cities like Bogotá, Medellín, Santiago, Buenos Aires and Lima there is reported that its inhabitants, in particular in the urban center, are exposed to sound pressure levels above the limit values which are displayed in national and international norms (Pacheco, Franco et al. 2009; Ortega and Cardona 2005; (Jaramillo, González Fernández et al. 2009); Platzer, Iñiguez et al. 2007; Cattaneo, Vecchio et al. 2008; Santos De La Cruz 2007).

In our country, the situation is very similar. Studies in cities or towns like Cuenca, Portoviejo, Quito, and Pujilí, mention levels of sound pressure in an amplitude between 55.5 dB and 80.8 dB, which is found in monitoring during the whole day. This is considered as a non-compliance of the rules in more than 90 % of the realized measurements regarding the norm NTE INEN-ISO 9613 and A.M. 097-A. This norm and ministerial agreement define the maximum limits of sound pressure in residential settlement areas until 50 dB at daytime and 40 dB at night, while in areas with hospitals and educational institutions until 45 dB at daytime and 35 dB at night, and finally in commercial mixed zones until 65 dB at daytime and 55 dB at night. This problem exists due to the high presence of vehicular traffic, commercial activities, and the inadequate use of soil which opposes the territorial plans of the cities (Gavilanes 2017; Loor 2017; Moya, Mora et al. 2018).

Currently, the self-reliant decentralized government of municipality of Ambato (GADMA) puts emphasis in the control of this type of pollution with the objective to implement actions for protection of the environmental quality. The project takes part of the Environmental Agenda of the period 2012-2018 under the execution and leadership of the Department of Environmental Management and is supported by the Honorable Provincial Government of Tungurahua (HGPT) through the Direction of Management and Quality of the Environment (DGCA), which is monitoring in bars and discotheques of specified sectors.

The objective of this work is to complement the accomplished monitoring processes in the city of Ambato, eminently in the Cevallos Avenue in the zone of the highest vehicular and pedestrian traffic jam. Moreover, another object is to make measurements at four strategic points of the Avenue which is considered as the main commercial line.

Materials and Methods

Location

The present research work was performed in one of the main arterial roads of the city of Ambato, the Cevallos Avenue with a length of 2 km. In that Avenue people undertake different activities of commerce, bars, restaurants, discotheques, and marketplaces. This explains the presence of an elevated flow of persons and vehicles every day. The altitude of the Cevallos Avenue is between 2545.5 masl. (at the intersection with Las Américas Avenue with the Railroad Market as a reference and the coordinates

17 M, 765021, 9863639), and 2585.5 masl. (at the intersection with Francisco Flor with the La Yahüira Bridge at the zone of bars and the coordinates 17 M, 765021, 9863639).

In figure 1, the scheme of Cevallos Avenue with its secondary arterial roads and the location of the sample points are indicated.

Figure 1.

Graphical representation of Cevallos Avenue in the city of Ambato.

Measurement points

To establish the measurement points of this research, locations with major movements of persons and vehicles are identified, also the weekdays of the different activities which imply a greater agglomeration of passerbys and vehicles, therefore with a higher acoustic disturbance. Four measurement points are obtained as a result (see figure 1).

1. Railroad Market
2. Modelo Market
3. Cevallos Park
4. La Yahüira Bridge

In table 1, the general information about the measurement points is presented, like as the maximum allowable limits of sound pressure after the standing legislation

Table 1. Location of measurement points and allowable maximum decibel limits.

Reference Point	Coordinates		Address	Characteristics	Allowable máximum limit (dB)	
	X	Y			Day	Night
Railroad Market	764927	9863417	Cevallos Avenue between González Suárez and Las Américas Avenue	Entrance to the car park of the Multiplaza commercial center " in front of the railroad market	60	50
Modelo Market	764276	9862826	Cevallos Avenue and Tomas Sevilla	Corner of the Model market in front of the Bayer farmacy	60	50
Cevallos Park	764072	9862637	Cevallos Avenue and Martínez	Corner of Cevallos Park in front of the La Providencia School	60	50
La Yahüira Bridge	763650	9862230	Cevallos Avenue and Francisco Flor	End point of Cevallos Avenue, zone of bars and discotheques	60	50

Used equipment and methods

In the four measurement points are noticed critical points of affectation, whilst sources of noise emitting sources, stationary sources of noise emission, and mobile sources of noise are measured.

The used measurement method is established in the Ecuatorian environmental legislation by the Unified Text of Secondary Legislation of the Environmental Ministry (TULSMA), in the VI. book, Annex V. The following information is found for the four measurement points: Minimum and maximum levels of sound pressure (NPS) expressed in decibels (dB), temperature of the environment, and the wind speed (km/h).

The used equipment and applicable national norms to conduct the work are presented in table 2.

Table 2. Used equipment and materiales, and applicable norms

Equipment and materials	Applicable norms
GPS	Agreement No. 097-A, 2015. Reform of TULSMA, annex 5: 5. About the determination of levels of noise emission by a stationary source of noise
Sound level meter	
Acoustic calibrator	
Computer	
Chronometer	
Software ArcMap 10.5	

The sound level meter is made of the brandmark CESVA, model SC310 with the date of calibration in 2017. To realize the measurements, this equipment is installed on a tripod at an height of equal or higher than 1.5 m above ground, setting up the microphone aiming the sound source with an angle of 45° to 90° above the plain horizon. During the measurement, the operator moved away from the device, at least 1 meter. The achieved information and also the location of the measurement points are represented in the software ArcMap 10.5. These points are selected based on technical and geographical information, provided by the Department of evaluation and cadasters (land registers) of the self-reliant decentralized municipality government of Ambato representing the locations of the biggest problems with noise pollution in the study area.

Results and Discussion

In the present work, the used wind speed data are determined by other performed studies in the survey area (Vargas L. C., 2015), or based on climatologic data (Climate data.org, 2018; Cedar Lake Ventures, Inc, 2018). All the values are below the standing limit of the Ministerial Agreement No. 097-A, 2015 of 5 m/s.

As well the humidity is examined, because with a high relative humidity of rainfall, it is not possible to measure due to occurrence of erroneous data. The data comes from Climate data.org, 2018, where a relative humidity of 0 % is set on the days of measurement.

In the same way in respect of the temperature, it is important to consider this factor, because the sound level meter can operate between 0 and 50 °C. In the case of temperature changes there can happen a condensation of water in the microphone (Vargas L. C., 2015). However, in the city of Ambato the mean temperature is 14,6 °C, in particular on the measurement days the values varied from 4 °C until 21 °C (Accu Weather, 2018). Thus, the monitoring is not affected.

The monitoring was done during two weeks in May 2018, from 14.05.2018 to 21.05.2018, in four measurement points with two continuous samples in every schedule. In total, there are 16 measurements, where reference points, coordinates, altitude, land use, date of measurement, mean wind speed, and temperature are noted, which is presented in table 3.

Table 3. Environmental characteristics of measurement points

Reference point	Coordinates		Altitude (msnm)	Land use	Date	Wind speed (km/h)	Temperature (°C)
	X	Y					
Railroad Market	764927	9863417	2548.2	Commercial	14/5/2018	8	11 a 19
					21/5/2018	8.5	13 a 16
Modelo Market	764276	9862826	2573.1	Commercial	14/5/2018	8	11 a 19
					21/5/2018	8.5	13 a 16
Cevallos Park	764072	9862637	2577.4	Commercial	11/5/2018	7.8	4 a 21
					18/5/2018	8.2	9 a 18
La Yahüira Bridge	763650	9862230	2584.7	Commercial	11/5/2018	7.8	4 a 21
					18/5/2018	8.2	9 a 18

Source: (Climate data.org, 2018, Accu Weather, 2018)

In the tables 4, 5, 6, and 7 are shown the detected sound pressure levels in the four measurement points, where the mean, minimum and maximum values are determined which show a range of mean values of the sound level meter in the Cevallos Avenue between 61 and 72 dB, as well in the night the mean values are between 49.4 and 74.4 dB.

Within the four distributed points along the Cevallos Avenue, a mínimum value of 57.8 dB on daytime is obtained in point 3 “Cevallos Park”, and a máximum value of 109.7 dB in point 4 “La Yahüira Bridge”, meanwhile at night a minimum of 57.5 dB is observed in point 1 “Railroad Market”, and a maximum of 117.8 dB in point 4 “La Yahüira Bridge”.

Table 4. Obtained data in measurement point 1.

Reference point	Coordinates X	Coordinates Y	Date	Schedule	Noise monitoring (dB) Min	Max	Total
Railroad Market	764927	9863417	Monday 14/05/2018	9:30-9:45	64.2	101.4	65.7
				9:50-10:05	66	97.4	72
				21:00-21:15	57.5	95.6	49.6
				21:20-21:35	58.9	10.,3	56.5
			Monday 21/05/2018	9:30-9:45	63.2	99.8	65.7
				9:50-10:05	62.9	98.3	63.2
				21:00-21:15	58.1	94.8	57.8
				21:20-21:35	58.5	99.2	49.4

Table 5. Obtained data in measurement point 2.

Reference point	Coordinates X	Coordinates Y	Date	Schedule	Noise monitoring (dB) Min	Max	Total
Modelo Market	764276	9862826	Monday 14/05/2018	10:30-10:45	68.2	100.2	66.5
				10:50:11:05	69.1	100.6	69
				21:50-22:05	72.8	100.5	60.9
				22:10-22:25	68.4	104.9	71.2
			Monday 21/05/2018	10:30-10:45	72.8	100.5	60.9
				10:50:11:05	68.4	104.9	71.2
				21:50-22:05	64.7	102.6	60.5
				22:10-22:25	64.9	102.8	64.7

Tabla 6. Obtained data in measurement point 3.

Reference point	Coordinates X	Coordinates Y	Date	Schedule	Noise monitoring (dB) Min	Max	Total
Cevallos Park	764072	9862637	Friday 11/05/2018	9:30-9:45	57.8	86.5	64.1
				9:50-10:05	57.8	86.1	69.4
				21:00-21:15	68.1	110	71.4
				21:20-21:35	65.7	99.7	69.8
			Friday 18/05/2018	9:30-9:45	67.2	95.8	61.7
				9:50-10:05	68.8	104.8	70
				21:00-21:15	64.5	98.9	67.5
				21:20-21:35	65.1	105.3	62.8

Table 7. Obtained data in measurement point 4.

Reference point	Coordinates X	Coordinates Y	Date	Schedule	Noise monitoring (dB) Min	Max	Total
Viaducto "La Yahüira"	763650	9862230	Viernes 11/05/2018	10:30-10:45	70.5	109.7	67.8
				10:50:11:05	69.3	82.9	66.2
				21:50-22:05	70.4	103	70.8
				22:10-22:25	71.7	106.9	74.4
			Viernes 18/05/2018	10:30-10:45	71.1	103.7	66.2
				10:50:11:05	70.1	104.9	68.9
				21:50-22:05	71.4	109.9	70.6
				22:10-22:25	76.0	117.8	71.8

Concerning the achieved data in the four measurements points and comparing them with obtained data in similar studies in the survey area, we establish that the data values of point 3 “Cevallos Park” are comparable to the measured values of a graduation thesis project at the Universidad Técnica de Ambato. In this work, corrected levels of sound pressure (LAeqk) of 71.9 dB are obtained in the Cevallos Avenue and Martínez, and 68.4 dB in Cevallos Avenue and Espejo, while in our measurement is observed a mean value of 66.3 dB.

Until then, another group (Burgos Arcos and Parra Narváez 2012) measured 72 dB as an equivalent weighted limit (Leq), which coincides in one of the measurement points of the present study. This point is located in the Cevallos Avenue and Joaquín Lalama and is higher than the mean value of all the surveyed points in our study. Related to the obtained maximum values, the maximum is 99.2 dB in measurement point 1, while in the work of the mentioned group (Burgos Arcos and Parra Narváez 2012) is 98 dB, hence both are similar. In none of the studies the noise emission is within the parameters of the environmental norm, because the standing allowable maximum limit at daytime is 60 dB.

This behavior is not present all over the city, because as a big city with different land use types, the developed environments are diverse. As an example, in the platform 4-zones North which is evaluated in a graduation thesis project at the Universidad Técnica de Ambato located in the parish Izamba Atahualpa and Martínez. There exists residential, agricultural, nature protection and in the main part commercial land use. In this place, there are mean values from 58.8 dB in the streets Alfonso Troya and Reyes to 70.8 dB in the Indoamérica Avenue and Pedro Vasconez. These are two out of 21 measurement points, whereof 86 % exceed 50 dB and in some cases they pass the allowable maximum limits. Meanwhile the obtained data in this study, a mean minimum value of 62.9 dB is registered corresponding to point 3 (see figure 2), whis is higher than the mean minimum value of the formerly cited research work of the University.

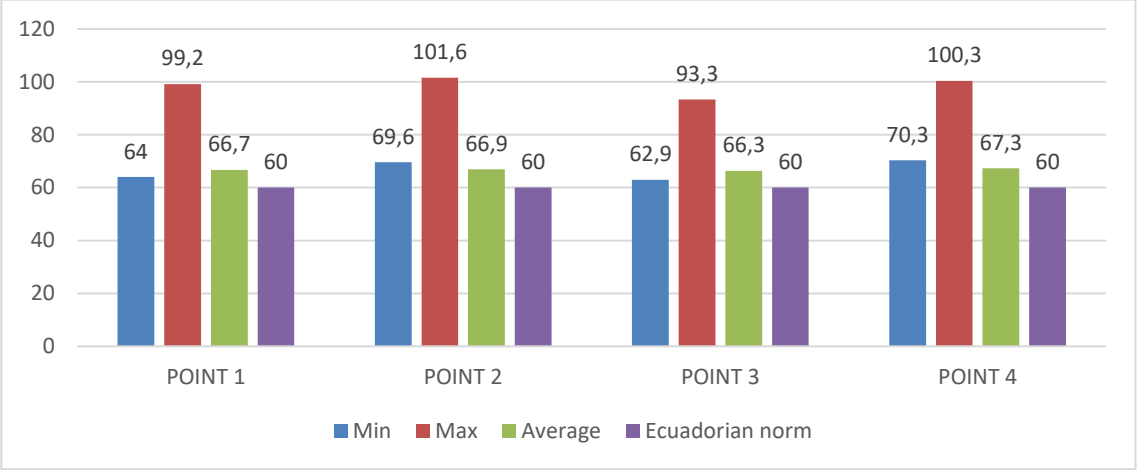


Figure 2. Results, in decibels, obtained in the daytime schedule 07:01-21:00

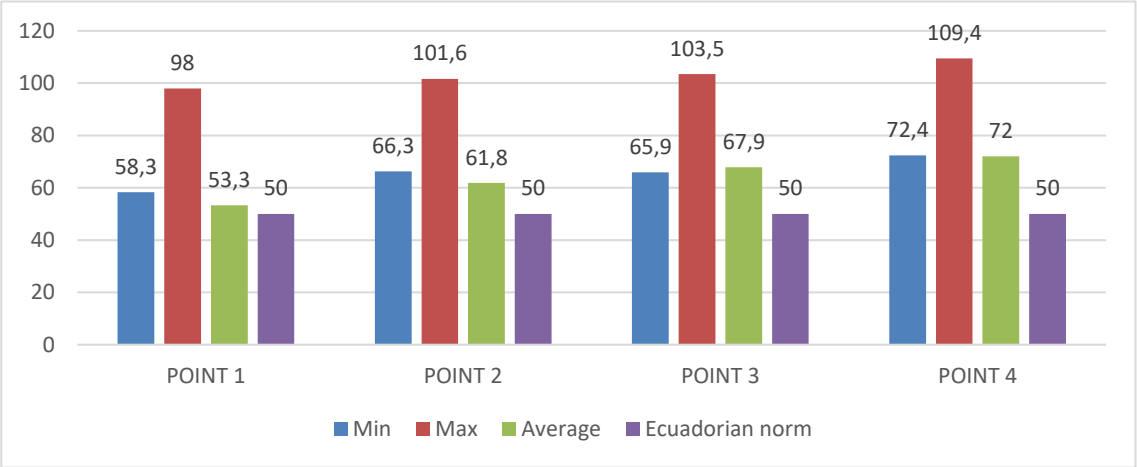


Figure 3. Results, in decibels, obtained in the nighttime schedule 21:01-07:00

Looking on the nighttime schedule from 21:01 to 07:00, one carried out a mean range between 53.3 dB in point 1 and 71.9 dB in point 4 (see figure 3) with a difference of 18.6 dB, which is higher than the one of the daytime (0.9 dB). This shows a higher variability of the level of sound pressure in the nighttime schedule.

Nevertheless, nor the measurement points of nighttime accomplish the allowable máximum limits of 50 dB in the commercial zone, since the measured mean minimum value is 53.3 dB in point 1, while in point 4 is registered a louder noise due to the influence of bars, discotheques, vehicles, and passerbys which circulate with a major frecuence in this time.

Conclusions

According to the obtained mean values, it can be noticed that the levels of sound pressure (NPS) increase in the nighttime period in the points 3 and 4 due to the presence of bars and discotheques which generate a high pedestrian and vehicular flow. Meanwhile in the points 1 and 2, the NPS in the nighttime schedule are lower than the ones of the daytime, though they do not comply with the applicable norm.

95 % of the obtained environmental levels of sound pressure exceed the allowable maximum levels of noise (LMP) of the standing Ecuadorian norm. Thus, regarding all measurement data, only 5 % accomplish this norm.

The noise pollution which is found in the surveyed area is produced by diverse sources, among them the very important ones: Installed resonators in cars, vehicles in bad conditions and unnecessary use of the horn (mobile noise sources), as well as stationary noise sources from informal merchants, emitted noise of their loudspeakers, alarms and sirens and the flow of pedestrians in the streets.

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