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Vehicles' noise at Sao Paulo: composition, problems and solutions

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Abstract

Excessive noise level in urban centers is a problem which causes many health diseases and, although gaseous emissions are getting down, noise remains high and exceeds the recommended levels from World Health Organization (WHO). The first step to deal with this is the Noise Map, a software tool that represents the noise level through a color scale over a map but usually without show the reasons of such level and neither evaluating the presence of motorcycles in the composition of the traffic flow. This article analyzes the noise contribution and particularities of different types of vehicles in the traffic of Sao Paulo City and looks for solutions to a quieter environment. It was measured road traffic noise of cars, motorcycles and buses and identified the main problems that contribute to keep it high. Cars appear as the most relevant source and their tires as the main influence in the Equivalent Sound Level (Leq). Motorcycles are the second biggest source, with high Leq and many vehicles above 80 dB(A) due to non-original mufflers and buses as the third, also with high Leq and many vehicles above 80 dB(A) but with significant influence of the cooling fan.

Introduction

Excessive noise levels in urban centers is generated for different sources as horns, airplanes, railways and road traffic among others [1] but noise from vehicles is the main annoying source especially during acceleration transients [2]. World Health Organization (WHO) points that there is strong relationship between noise and cardiovascular diseases, cognitive impairment, sleep disturbance, tinnitus and annoyance and there is an exponential correlation for people exposed to high noise level and myocardial infarction [2]. Urban noise level is above WHO recommended levels in many cities around the world, it is usual to found Equivalent Sound Level (Leq) above 70 dB(A) during the day [3, 4, 5, 6, 7] and, to make this matter worse, sound pollution is growing up while gaseous emissions are declining in many urban centers [2].

The objective of this article is to discuss about theoretical and actual environmental sound level of arterial roads of a region in Sao Paulo City, analyzing the contribution of each type of vehicle in compounding total sound level, identifying main sources and their problems to looking for solutions for a healthy environment.

Calculating Sound Level: Noise Map

Noise Map is a very useful tool that allows analyzing a city or a specific region in terms of noise level. While in Europe, since 2007, is mandatory for all cities bigger than 250,000 inhabitants to have their noise map [8], Brazil is slowly adopting this tool. Some cities as Brasilia and Fortaleza have their, while Sao Paulo City, the biggest city of Latin America, hasn't its one yet although there are just few academic studies for specific sites or districts.

To produce a Noise Map of a region, at first samples of the noise level are taken in strategic points and together with parameters such as traffic flow composition, traffic velocity, presence and kind of sound reflective surfaces, etc., the software projects a color scale over a map [4], as shown below in Figure 1.

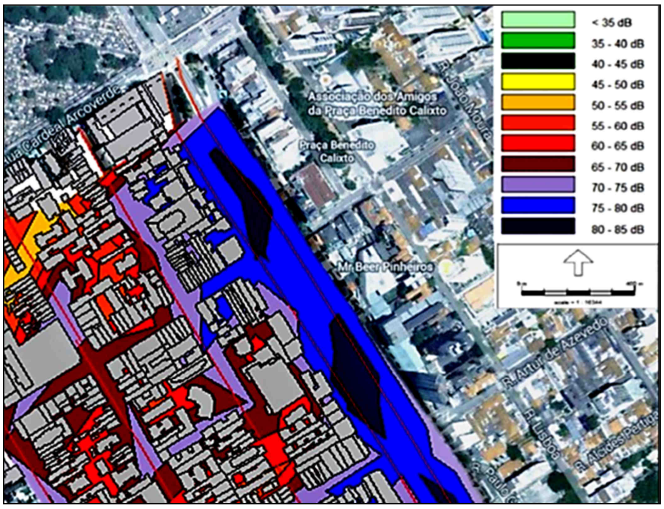

Figure 1 – Noise Map of Henrique Schaumann Avenue, Sao Paulo [4]

One limitation frequently found in this kind of software is to classify the vehicles just in two categories, light and heavy (LV and HDV) however motorcycles usually are computed as light vehicle although their noise emission is similar to a HDV. This question gets worse in Sao Paulo due to the significant presence of motorcycles in the traffic flow of arterial roads, about 15% [9], similar problem found in Taiwan by Chang [7]. Other limitation of Noise Map is that this tool just offers a general picture, without details or causes of excessive noise so it is necessary to go beyond through field analysis to understand the whole frame.

Measuring Environmental Noise

Method

To generate basic data to allow a better analysis of urban noise of Sao Paulo City it was necessary to do roadside measurements. This work was divided in three parts: first it was made an evaluation of

Equivalent Noise Level (Leq) in an arterial road to define how much which category is contributing to the general noise level, second an measure of how many vehicles are exceeding a reference value of 80 dB(A) to identify the ones who causes more annoyance and third was made an specific evaluation of noise emitted from cooling system fan of buses. Step One (Leq) and Two (vehicles above 80 dB(A)) were made in the crossing of Teodoro Sampaio Street with Brigadeiro Faria Lima Avenue, Sao Paulo City. These arterial roads are both four lanes with intensive flow at typical urban velocities (25-50 km/h) and a massive presence of cars, motorcycles and buses. There are almost no trucks because a city law doesn't allow them in the city downtown during the day. To evaluate general Leq the sound level meter (SLM) was set in Leq mode and positioned 1.2 m high and at minimum 2 m far from sound reflecting surfaces and each measurement was done for 5 minutes without interruption. To register the specific Leq for each vehicle category the SLM was started typically when traffic flow consists only of cars or motorcycles or buses and was stopped when the flow changed, meaning that "specific Leq" in this study is a sum of short measurements of about one minute which results in a respective level. For Step Two, to measure how many vehicles produces more than 80 dB(A), SLM was set in Lp mode (sound level pressure mode) and traffic was under observation to identify noisy vehicles. Concerning Step Three, evaluation of noise from cooling system fan of buses, measurements were done close to bus stations in Sao Paulo, in the districts of Pinheiros and Tamaduatei, and in a city close to Sao Paulo, Santo Andre. SLM was set in Lmax mode to register maximum noise level and was put to 1.2 m high and 2 m far from sound reflective surfaces. The buses were measured running at typical urban speed, about 25 km/h, and in sites where is necessary accelerating the vehicle to pass by there.

Results and discussion

All field measurements were made during the period since February to May/2015. For Leq evaluation was expended two days and these data was crossed with traffic flow composition from Traffic Engineering Company of Sao Paulo (CET) [9]. To identify vehicles emitting more than 80 dB(A) were measured one hundred cars, fifty motorcycles and fifty buses and these results are shown in Table 1.

Table 1 – Traffic composition and measured data

	Traffic Flow [9]	**Specific Leq dB(A)**	**Contribution to Leq**	**> 80 dB(A)**
Cars	80%	72.6	64%	2%
Motorcycles	15%	75.5	23%	16%
Buses	3%	77.5	7%	36%
Others	< 2%	-	< 5%	Not meas.
General Leq (calculated):		***73.6***		
General Leq (measured):		***73.8***		

As shown above, cars are the main source of urban road noise; although this kind of vehicle has the littlest Leq they have a massive presence in traffic flow. It means that if reducing just few dB(A) at its running noise will produce a great final result, for example a reduction of 2 dB(A) in car's Leq will reduce 1.2 dB(A) in general Leq and resulting in an estimated level of 72.4 dB(A). About annoyance, cars are not so important because only 2% of them were found producing noise over 80 dB(A), in all cases due to lack of maintenance in exhaust systems.

The motorcycles are the second main source, with a specific Leq significantly higher than cars and close to that of HDV. The amount recorded above 80 dB(A) is greater also, 16%, and it was also been observed that some motorcycles emit more than 90 dB(A), mainly due to the use of tampered or non-original exhaust systems (NOES). NOES' manufacturers usually avoid using catalysers to keep the selling price lower than that of an original system from the manufacturer (OEM) and these replacement mufflers have also fewer internal parts than an OEM in order to reduce gas flow counter-pressure, but generating much more noise. The lack of in-use inspections contributes to owners choosing cheaper-but-noisy-and-polluting NOES instead of original parts. About 90% of these mufflers, freely sold in the aftermarket, are of the model called "estralador", shown in Figure 2, who produces a loud "popping", especially when the rider runs the engine in median-high velocities and suddenly closes the throttle. It has an external shape similar to the original one but internally hasn't any sound absorbing system, so it can generate noise up to 12 dB(A) higher than an OEM [10]. Due this, the motorcycles' influence in general Leq is more significant than their presence in the traffic flow. For example, it is estimated that if the motorcycle rate in the traffic reaches 37% they will be responsible for producing 50% of the general Leq.

Figure 2 – Replacement muffler with no sound absorbing system inside

At end, buses appear as the third main noise source. Although their contribution in the general Leq is not so strong (7%) due to the low amount on traffic flow, on other hand their annoying potential is very high because there is a large quantity (36%) producing more than 80 dB(A), as shown in Figure 3, that can cause deep discomfort in people on streets.

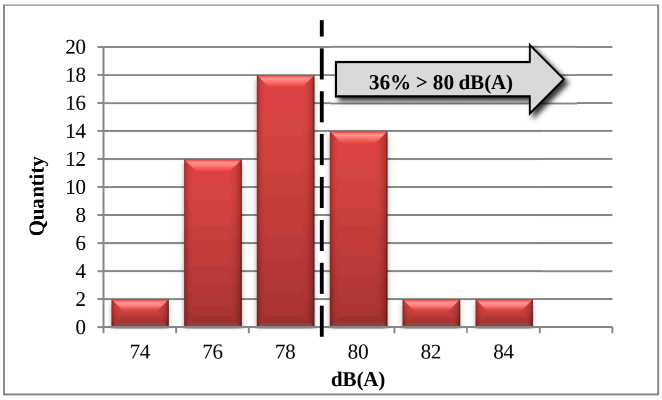

Figure 3 – Buses: field measurement of noise level

The reasons to exceed 80 dB(A) pass for lack of maintenance, excessive acceleration and, many times, for the noise generated for the cooling system fan. Surely fan noise is highly ambient temperature dependent but during field measurements it was about 25°C, not so hot for a tropical city as Sao Paulo, where is usual temperatures varying about 30-35°C in Spring and Summer when problems of noise from fan ought get worse.

The third step, evaluation of noise from cooling system fan, was developed in three different places. It was measured seventy five buses and the license plate of all vehicles measured were registered in order to, by a search in the internet, accessed registration data as manufacturer, model and year of manufacturing and be able to check influence of manufacturers' brand and models. However it was not found strong relationship among these parameters for noise level as well vehicle's age, velocity and occupation rate also do not show major influence, so still remains as reason for excessive noise if cooling fan is working or not. Of the vehicles evaluated, thirty three of seventy five buses (44%) were running with fan on with a Lmax average 4.2 dB(A) higher than buses with fan off and 100% exceeding 80 dB(A), as shown in Figure 4.

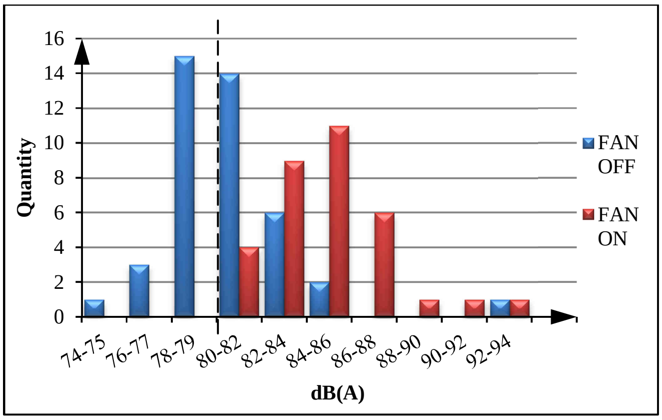

Figure 4 – Buses' cooling system fan evaluation

Problems and Solutions

Cars: tires, lack of maintenance

Since beginning, measurement of car's noise for type approval in Brazil is done in full acceleration mode, also known as Wide Open Throttle (WOT) but it is not a typical driver's behavior because actual urban driving is a mix of partial and full acceleration and constant speed. While WOT produces more noise from exhaust system, in constant speed tires are more relevant [11] and became a significant point to help reduce cars' Leq. In order to control and reduce tire noise, Europe has put in force the Directive 2001/43/EC [12] and Brazil, following this example, introduced an ordinance by National Institute of Metrology, Quality and Technology (INMETRO), Portaria 544/2012 [13], which determines tire noise limits among other requisites and will enter in force after 2017, so there is an expectancy to reduce car's contribution on general urban Leq.

About the lack of maintenance what results in 2% of cars emitting noise above 80 dB(A), to solve it is mandatory to restart in-service vehicle inspection. In Brazil there is just an example from Sao Paulo City, where vehicular inspection happened since 2008 to 2013 and brought positive effects that could be felt at that time about cars conservation and preventive maintenance.

Motorcycles: tampered/non-original mufflers

Modified motorcycles are usual all around the world, in Europe is found 35% of motorcycles and 65% of moped with tampered mufflers emitting excessive noise and in Japan 40%, usually without catalyzer in the exhaust pipe [14, 15]. The rate of noisy vehicles found in our field measurement (16%) is lower than in Europe and Japan but their environmental impact is higher because motorcycle presence in Brazilian traffic flow is about three times bigger than in Europe [9,14].

There are many reasons to change or modify original mufflers for noisy ones, as to try improving performance or producing a "sportive" sound but mainly the choice for "estralador" model for professional riders, also called "motoboys", comes of the intention of to be heard in the middle of traffic jam and so avoid incidents with cars drivers, or in others words, for "safety" [10].

A matter of occupational health emerges from this "safety" because these professionals are the closest people exposed to the noise produced for their own noisy motorcycles and so are subjecting themselves at five factors that produce Noise-Induced Hearing Loss (NIHL) [16, 17]. The first, high sound level pressure, sometimes more than 90-95 dB(A) adding that helmets can increase sound pressure at about 5 dB(A) [16], so it could consider that riders are under noise level of up to 95-100 dB(A). The second factor is exposition's time to noise and they are working and are been exposed to above 85 dB(A) for more than eight hours a day and, according Brazilian Ministry of Labour [18], this combination of noise level plus time of exposition is configured as hazardous work. The third factor is the sound tone and "estralador" mufflers typically have high sound pressure in high frequencies in order to produce the alert effect. The fourth factor is about gender, because men are more susceptible to NIHL than women and almost all professional riders in Sao Paulo are male. Lastly, the fifth factor is the presence of mechanical vibrations and they are continuously subjected to motorcycle's vibration from engine and street irregularities.

The search for solutions to restrain noisy mufflers is very hard, it is not just a matter of prohibiting to sell in the aftermarket an exhaust system what will produce noise over legal limits. Europe since early '90s has laws prohibiting selling non homologated exhaust systems but owners/riders easily can buy illegal systems from other countries by internet sites [14]. In Brazil there's Portaria INMETRO 123/2012, to regularize silencers' aftermarket but it was delayed to enter in force, there is a forecast to starts at 2017 although initial deadline was 2015. Solutions should pass through roadside control, in service inspection, awareness advertisements and more. It should be necessary a broad and coordinated effort to change it.

Buses: cooling system fan

International procedures to evaluate vehicle's noise as ISO 362 and Regulation UNECE 51 and Brazilian normative ABNT NBR 15145 determine that during the measurements the cooling fan must be off [11, 19, 20], due this there aren't any official data for fan noise since the beginning to now of HDV homologation in Europe and Brazil, so it is how to consider that noise of cooling fan not influences urban sound pollution but when a cooling fan is working, it adds in the noise level about 2 up to 6 db(A). How buses' manufacturers tend to produce them close to homologation limits there is no gap to include this adds.

Solutions for cooling fan noise of HDV can be found in light vehicles, as blades with scimitar profile and variable pitch (see Figure

5) and surely it will be necessary to discuss and define methods to control and limits to HDV cooling fan noise.

Figure 5 – Car cooling fan with scimitar blades and variable pitch

Conclusions

To achieve a reduction in urban sound pollution is necessary to work simultaneously in many different ways, Noise Map as diagnosis tool is a helpful instrument but it is mandatory to develop and implement in-service inspection, roadside control, awareness advertisements, engineering development and more. Because each type of vehicle in the roads has particularities that should be understood in order to reduce urban sound pollution, it is very important to pay attention to cars' tires homologation, noisy motorcycle mufflers sold in aftermarket and buses' cooling fans. It passes through see vehicles in the cities as the main source of noise and just developing quieter vehicles we will reach a quieter urban environment.

References

1. BRÜEL & KJAER, "Environmental Noise", available in: http://www.bksv.com/Library/Primers, access in April/02/2015.
2. WORLD HEALTH ORGANIZATION – WHO, "Burden of disease from environmental noise: Quantification of healthy life years lost in Europe", WHO Regional Office for Europe: Copenhagen, p. 126, 2011, available in: http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf , access in July/20/2015.
3. ZANNIN, P. H. T., "Aspects of urban noise pollution in a large Brazilian city", Noise Notes: 23-32, July/2004.
4. VIANNA, K. M. de P., "Poluição sonora no município de São Paulo: avaliação do ruído e do impacto da exposição na saúde da população", PhD. thesis, Faculdade de Saúde Pública da Universidade de São Paulo – FSP-USP, Sao Paulo, 2014.
5. DA SILVA, A. S. M., "Acústica Ambiental: análise do ruído urbano", M.Sc. dissertation, Universidade do Porto, Porto, Portugal, 2009.
6. MOHAMMAD, H. E. et al., "Noise pollution in urban environments: a study in Yazd City, Iran", Polish Journal of Environmental Studies: 1095 – 1100, 2012, available in: http://www.pjoes.com/abstracts /2012/Vol21/No04/35.html, access in June/09/2015.
7. CHANG, T., et al., "A modified Nordic prediction model of road traffic noise in a Taiwanese city with significant motorcycle traffic", Science of total environment: 375-381, July/2012. Available in: http://www.sciencedirect.com/science/article/pii/S0048969712008315, access in May/11/2015.
8. European Community – EC, "Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise", Eur-lex: access to European Union Law, 2002, available in: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32002L0049, access in December/02/2015.
9. Traffic Engingerring Company – CET, "Pesquisa de monitoração da fluidez: desempenho do sistema viário principal, volume e velocidade – 2013", 2014, available in: http://www.cetsp.com.br/sobre-a-cet/relatorios-corporativos.aspx, access in April/29/2015.
10. FORCETTO, A. L. S., "Poluição sonora urbana: a influência de modificações em escapamentos de motocicletas na emissão de ruído", MSc dissertation, Faculdade de Saúde Pública da Universidade de São Paulo – FSP-USP, Sao Paulo, 2016.
11. The International Organization for Standardization – ISO, "Measurement of noise emitted by accelerating road vehicles – engineering method – Part 1: M and N categories", ISO 362-1, Rev. January/2015.
12. European Community – EC, "Directive 2001/43/EC of the European Parliament and of the Council of 27 June 2001 amending Council Directive 92/23/EEC relating to tires for motor vehicles and their trailers and to their fitting", Eur-lex: access to European Union Law, 2002, available in: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32001L0043, access in December/02/2015.
13. Instituto Nacional de Metrologia, Qualidade e Tecnologia – INMETRO, "Portaria nº 544/2012: Requisitos de avaliação da conformidade para pneus novos", October /29/2012.
14. Association des Contructeurs Européens de Motocycles – ACEM, "Striving against traffic noise: how powered two-wheelers can contribute", 2014, available in: http://www.acem.eu/index.php/policy-access/environment/noise-reduction, access in October/30/2014.
15. United Nations Economic Commission for Europe – UNECE, by Ministry of the environment, Japan, "Current framework of vehicle noise regulation in Japan – Informal Document GRB-56-18", 2012, available in: http://www.unece.org/fileadmin/DAM/trans/doc/2012/wp29grb/ECE-TRANS-WP29-GRB-56-inf18e.pdf, access in March/25/2014.
16. DE CONTO, J., "Exposição ao ruído e proteção auditiva em moto-taxistas", PhD. thesis, Universidade Federal de Santa Catarina, 2009.
17. ARAÚJO, S. A., "Perda auditiva induzida pelo ruído em trabalhadores de metalúrgica", Revista Brasileira de Otorrinolaringologia: n. 1, p. 47-52, January-February/2002, available in: www.scielo.br/pdf/rboto/v68n1/8770.pdf, access in July/06/2015.
18. Ministério do Trabalho e Emprego – MTE. Norma Regulamentadora 15: Atividades e operações insalubres, updated in Aug/13/2014. Brasília, 2014, available in: http://portal.mte.gov.br/legislacao/norma-regulamentadora-n-15-1.htm, access in Sept/28/2015.
19. United Nations Economic Commission for Europe – UNECE, "Uniform provisions concerning the approval of motor vehicles having at least four wheels with regard to their noise emissions" Regulation No. 51, E/ECE/324/Rev.1/Add.50/Rev.2−E/ECE/TRANS/505/Rev.1/Add.50/Rev.2, 2011.
20. Associação Brasileira de Normas Técnicas – ABNT, "Acústica – Medição do ruído emitido por veículos rodoviários automotores em aceleração – método de engenharia" ABNT NBR 15145, November/2004.

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Definitions/Abbreviations

ABNT Brazilian Association of Technical Standards

CET Traffic Engineering Company of Sao Paulo State

cooling fan Fan mounted together the radiator to induce air flow and so reduce/control the engine’s temperature.

HDV Heavy duty vehicles: power-driven vehicles having at least four wheels and used for the carriage of passengers or goods and having a maximum authorized mass above 3,500 kg. E.g.: buses and trucks.

INMETRO National Institute of Metrology, Quality and Technology

Leq Equivalent noise level: it is the level that would represent the amount of energy present in the measured, fluctuating sound pressure level.

LV Light vehicles: power-driven vehicles having at least four wheels and used for the carriage of passengers or goods and having a maximum authorized mass below 3,500 kg. E.g.: cars, vans, SUVs.

NIHL Noise-Induced Hearing Loss

SLM Sound level meter

UNECE United Nations Economic Commission for Europe

WHO World Health Organization

WOT Wide Open Throttle: drive mode when the engine admission throttle is fully opened to result in maximum acceleration