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NOISE CONTROL FOR A BETTER ENVIRONMENT

Assessment and profiling of acoustic solutions for mitigating the noise levels originating from hydrosanitary facilities in buildings

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ABSTRACT

Excessive noise is deemed a public health problem due to its impact upon human health. Within such context, the need for acoustic control in residential buildings is highlighted, and as regards this study specifically, with respect to noise control in buildings' hydrosanitary facilities. Such high noise levels may arouse unpleasant auditory perceptions, generating embarrassment among neighbors due to the lack of privacy. This article's goal is to evaluate the outcomes of possible acoustic solutions for mitigating the sound pressure levels generated by hydrosanitary facilities in buildings, due to toilet flushing activation as well as from the opening of water taps. Sound pressure levels measurements have been carried out according to the ISO 16032: 2004 standard as adapted for lab purposes within IPT's hydrosanitary acoustic essay chamber, for nine samples of acoustic envelopment. Such technical results arising from the physical quantity L_{Zeq} were evaluated for each of the samples, as measured both in acoustically-enclosed as well as in bare pipes. Concerning the samples under assessment, the results were deemed satisfactory, since most of the samples present differences in terms of the global sound pressure levels, $L_{Zeq,nT}$, equalling $\Delta L \geq$ 20 dB upon toilet flushing and $\Delta L \geq$10 dB for the noise levels arising out of tap opening events.

Keywords: Hydrosanitary noise, Toilet flushing, Taps
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1. INTRODUCTION

In the residential buildings without a proper acoustic design, the noises emitted by hydrosanitary facilities are always noticed, regardless of either the number of floors and apartments or yet the social class to which the building is destined. Due to rationalizing procedures, construction companies have been replacing iron pipes for PVC (Polyvinyl chloride) ones, besides the fact that these have come to be installed between ceilings, instead of slab-embedded facilities. Such facilities must be suited to acoustic design in order to not generate discomfort for buildings' users [1]. Whenever projects not following acoustic guidelines are considered, the noise originating from such facilities constitutes the source for most user complaints, mainly between distinct units [1, 2]. Such noise causes unpleasant hearing sensations and may sometimes create estrangement between neighbors, leading to possibly embarrassing situations [1, 3].

Project and execution guidelines regarding residential building facilities with respect to cold, hot, rainwater and sanitary sewers are provided by Brazilian standards NBR 5626 [4], NBR 7198 [5], NBR 10844 [6] e NBR 8160 [7], which report that piping systems and hydrosanitary appliances must not cause excessive noise, but such standards only indicate maximum fluid velocity and pressure flow values, something which is not sufficient for designing a suitable acoustic project for the mitigation of noise and vibrations stemming from hydrosanitary facilities. On the other hand, the performance standard for buildings, NBR 15575 [2], recommends that hydrosanitary facilities do not produce high sound pressure levels within dormitories. The standard sets forth the noise limits within dormitories as generated by the use of hydrosanitary facilities, according to equipment's operating cycles.

Mitigating the sound pressure levels generated by hydrosanitary facilities is something critical in order to assure acoustic comfort for the inhabitants within a building. There are studies in Brazil in order to find out which mechanisms could account for noise emission in hydrosanitary facilities [3], on suitable methods for measurement or else which quantities should be measured in order to better quantify the noise that comes out of such types of equipment [8]. Nonetheless, no studies have been set in order to compare the acoustic performance between the existing solutions available in the national market so as to reduce the sound pressure levels originating from hydrosanitary facilities through measurements carried out in controlled and identical environments.

Hence, this article's main goal is to assess the performance of acoustic solutions made available in the Brazilian market and destined to attenuate the sound pressure levels generated by buildings' hydrosanitary facilities - in this case, the flushing of toilets and the opening of taps.

The sample measuring method as well as the characteristics regarding each sample, follow in Section 2. Section 3 contains the results of the essays performed and the comparisons between each sample and the limits of the NBR 15575: 2013 standard. Last, Section 4 presents this article's conclusion.

2. METHODOLOGY

This section describes the method employed for measuring samples and presenting selected samples for the study under consideration.

2.2.1. Essayed samples

The possible acoustic solutions generally employed in Brazil for mitigating hydrosanitary noise have been researched. Based upon this, authorizations have been asked toward suppliers for carrying out acoustic performance essays within controlled environments - in this case, within the hydrosanitary noise essay chamber from the laboratory of the Instituto de Pesquisas Tecnológicas (IPT) in Brazil.

The description of the composition for each essayed sample, their thicknesses and densities, follows on Table 1. A total of nine samples have been essayed and evaluated, these constituting the main products available in the Brazilian market currently.

Table 1: Samples essayed within an identical and controlled environment.

Samples	Description	Thickness	Density
A	Polyurethane-pressed rubber residues	Blanket: 0.10 in Curve and box: 3.93 in	68.67 lb/ft^3
B	Closed-cell elastomeric foam	Blankets and pipes: 0.393 in	3.121 lb/ft^3
C	Closed-cell elastomeric foam	Blankets and pipes: 0.787 in	3.121 lb/ft3^3
D	Open-cell elastomeric foam	Blanket: 0.59 in	7.49 lb/ft^3
E	Fiberglass	Pipes: 0.984 in	4.68 lb/ft^3
F	Heavy-layer non-fabric blanket (felt), covered, aluminized material	Adds up to 0.511 in	Surface density: 12.90lb/ft^2
G	Polyethylene and heavy layer (green colored)	Adds up to 0.196 in	No info available
H	Polyethylene, heavy layer (green colored), closed-cell elastomeric rubber	Adds up to 0.295 in	No info available
I	Asphalt blanket structured over non-fabric material and produced from special asphalt coupled to high-grammage geotextile blanket	Adds up to 0.118 in	49.94 lb/ft^3

2.2.2. Chamber

In order to check and compare the acoustic performance of essayed samples, acoustic essays were carried out in controlled and identical environments, namely IPT's hydrosanitary noise essay chamber.

A partnership with acoustic material suppliers was therefore established in order to carry out acoustic measurements, both with the lady who authors this paper as well as with IPT. The fitting of samples within the chamber took place on account of the suppliers themselves and the measurements were performed by the IPT staff, both phases having been closely followed by the authors.

The volume of the chamber intended for hydrosanitary essays equals approximately 1906 ft^3. The reverberation time for the lower floor room where measurements were performed at 500 Hz is roughly 2.38 seconds. There follows, on Figure 1, the image of the chamber located on the lower floor. The upper floor comprises an experimental bathroom fitted with a shower, an Esteves brand tap and a toilet with associated container from the DECA brand (1.58 gallons per flush).

Figure 1: IPT hydrosanitary essay chamber's lower floor.

The slab is decoupled from the structure, possessing resilient materials in its contact base, both with respect to the construction beam and its lateral edges. It's made up by a metallic structure and a conventional concrete slab, approximately 6.29 in thick. Vertical internal seals are made up of double plasterboards whose insides are filled up with rockwool, total thickness 4.72 in. The double door has got fireguarding properties.

2.2.3. Method used for sample measurements

The measurement procedure was based upon the ISO 16032: 2004 [9] standard so as to find out the following acoustic parameters: standardized equivalent sound pressure level over 1/1 octave frequency bands, $L_{\text{Zeq, nT}}$, A-weighted standardized equivalent sound pressure level, $L_{\text{Aeq, nT}}$, maximum standardized sound pressure level with S setting and A weighting, $L_{\text{ASmax, nT}}$, and reverberation time (T_{60}) regarding the sound intake room over frequency bands, performed according to the ISO 3382-2 [10] standard.

The following equipment were used for performing measurements: 01 dB Blue Solo sound meter, MNS-03, IPT calibration number 152 131-101, expiry month 07/2018, 01 dB Blue Solo, MNS-03 sound meter filter, MNS-03, IPT calibration number 153 035-101, expiry month 08/2018, 01 dB CAL 21 acoustic calibrator, CNS-09, IPT calibration number 152 155-101, expiry month 06/2018 and Brüel & Kjær - OmniPower 4292 omnidirectional sound source.

The system's standard operational cycle consists in flushing/filling activations of the flushing container, totalling 30 seconds. Regarding taps, it consists in the activation of timed taps, namely 5 seconds.

To that end, measurements were performed in the positions below, according to the floorplan presented in Figure 2, wherein: Measurement spot 1 is given by the highest L_{Cmax} value measured between measurement spots C1, C2, C3 and C4; Measurement spots 2 and 3, corresponding to two positions within the reverberant field; 03 positions for the omnidirectional sound source, in order to obtain the reverberation time regarding each sample.

2.2.4. Data processing

In order to obtain the weighted equivalent sound pressure level in A, $L_{\text{Aeq, nT}}$ and the maximum sound pressure level, with integration time set to slow, A-weighted, L_{ASmax}, due to toilet activations or yet to tap openings, the following items have been carried out:

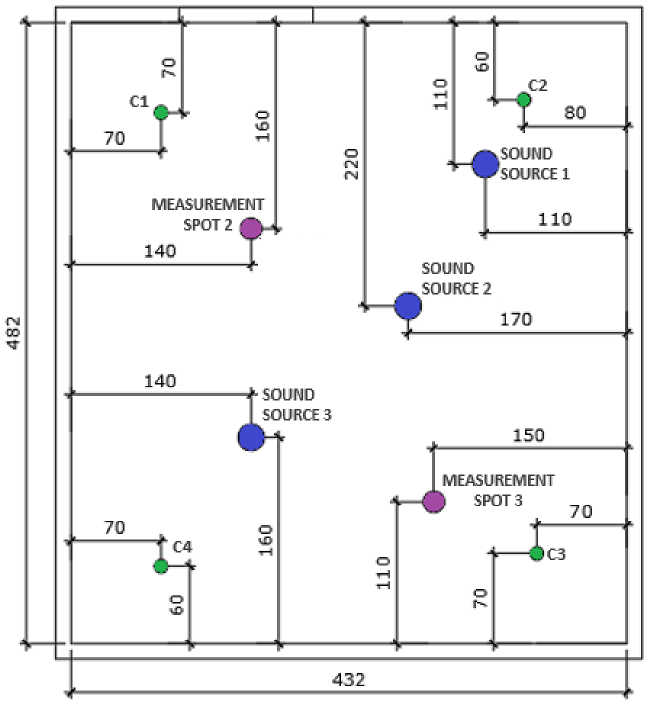

Figure 2: Microphone and sound source positions in centimeters – lower floor.

1. calculation of the mean of the results measured over three measurement spots considering each magnitude and frequency, through Equation 1:

$$L_{\text{Zeq}}\text{mean} = 10\log_{10}\left(\frac{L_{\text{Zeq}}(\text{P1}) + L_{\text{Zeq}}(\text{P2}) + L_{\text{Zeq}}(\text{P3})}{3}\right); \tag{1}$$

   considering that,
   L_{Zeq}mean, is the mean equivalent sound pressure level between measurement spots 1, 2 and 3, measured in dB;

2. carrying out the same procedure in order to obtain the mean between the three sound pressure level measurements – with integration time set to slow on and maximum L_{Smax} and also for the three background noise measurements, L_{Zeq};

3. carrying out corrections regarding background noise:

   – if the background noise sound pressure level is 10 dB or over, below the sound pressure level of the equipment in operation, no correction must be applied, that is:

$$L_{\text{Zeq corrected}} = L_1; \tag{2}$$

   in which
   $L_{\text{Z eq corrected}}$ corrected is the corrected sound pressure level in dB;

   L_1 is the sound pressure level measured over octave frequency bands from the equipment in operation, including the background noise in dB.

– if the sound pressure level of the background noise is from 4 dB to 10 dB below the sound pressure level of the equipment in operation, the measured sound pressure level must be corrected according to Equation 3,

$$L_{\mathrm{Z\ eq\ corrected}} = L_1 - \left(-10\log\left(1-10^{-0,1\times(L_1-L_2)}\right)\right); \tag{3}$$

where L_2 is the sound pressure level of the background noise over octave frequency bands, measured in dB.

– if the sound pressure level of the background noise is less than 4 dB below the sound pressure level of the equipment in operation, the measured sound pressure level must be corrected according to Equation 4:

$$L_{\mathrm{Z\ eq\ corrected}} = L_1 - 2,2. \tag{4}$$

4. performing standardization of results according to Equation 5:

$$L_{\mathrm{Zeq,\ nT}} = L_{\mathrm{Z\ eq\ corrected}} - 10\log_{10}\left(\frac{T_{60}}{0,5}\right); \tag{5}$$

where:
$L_{\mathrm{Z\ eq,\ nT}}$ is the standardized sound pressure level;
T_{60} is the reverberation time as measured within the sound intake room according to the ISO 3382 standard.

5. performing an A-weighting of results over octave frequency bands in order to obtain the standardized equivalent sound pressure level, weighted in A, $L_{\mathrm{Aeq,\ nT}}$.

6. the same procedure is performed once more so as to obtain $L_{\mathrm{ASmax,\ nT}}$.

3. RESULTS

The results presented in this section have already incorporated the necessary corrections due to background noise and reverberation time. Hence, these may be compared to the recommendations from performance standard, according to the values presented in Table 2. Please be reminded that the results presented have been measured within an identical and controlled environment, lacking a ceiling between measurement spots and piping.

Table 2: Hydrosanitary facility noise limits.

	Minimum values	**Intermediate**	**Superior**
$L_{\mathbf{Aeq,nT}}$	37 dB	34 dB	30 dB

Source: NBR 15575-6:2013 [2].

For comparison purposes, the logarithmic mean between the five results was calculated considering bare piping essays. All bare piping essays were performed by using the same piping made up of PVC. Please be reminded that we have made use of five suppliers plus nine essayed samples. And the essays performed through the use of bare piping (piping lacking acoustic enclosures) have been performed for each supplier individually.

3.3.1. Results due to toilet flushing activation

Therefore it becomes possible to evaluate and compare results ($L_{\mathrm{Zeq,nT}}$) regarding the nine samples essayed by means of both Figure and Table 3 due to toilet flushing activation. The results $L_{\mathrm{Zeq,nT}}$ reduce sound pressure levels, mainly between the band of frequencies extending from 500 Hz to 8000 Hz (a range in which human hearing is more sensitive), except for the results from Samples A and B. The ISO 16032 standard demands presenting results within octave frequency bands to one decimal place and the A-weighted results, rounded to the nearest whole number.

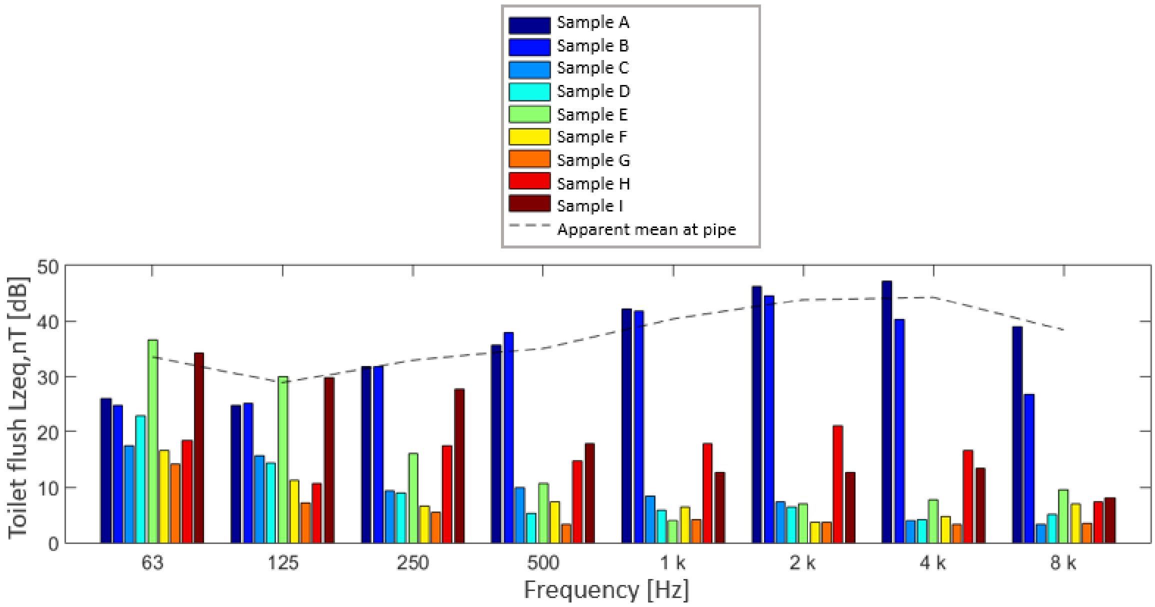

Figure 3: Comparison of $L_{Zeq,nT}$ values between essayed samples due to toilet flushing activation.

Table 3: $L_{Zeq,nT}$ values due to toilet flushing activation.

Frequency Hz	A	B	C	D	E	F	G	H	I	Bare pipe
63	26,1	24,8	17,5	22,8	36,6	16,5	14,2	18,5	34,2	33,5
125	24,7	25,1	15,6	14,4	30,0	11,2	7,1	10,7	39,8	28,8
250	31,8	31,8	9,4	9,0	16,0	6,6	5,5	17,5	27,7	32,8
500	35,6	37,9	9,9	5,3	10,6	7,3	3,3	14,7	17,9	35
1000	42,2	41,7	8,4	5,8	4,0	6,4	4,2	17,9	12,6	40,4
2000	46,2	44,6	7,3	6,3	7,0	3,7	3,6	21,0	12,7	43,8
4000	47,1	40,3	3,9	4,1	7,6	4,8	3,3	16,6	13,4	44,2
8000	39,0	26,8	3,2	5,1	9,5	7,0	3,5	7,3	8,0	38,4
Global (A)	**52**	**48**	**14**	**13**	**18**	**13**	**11**	**25**	**23**	**49**

Samples G, F and C stood out especially, respectively ranked according to their best acoustic performance. The global difference between sound pressure levels, $L_{\mathrm{Zeq,nT}}$, regarding the mean as calculated for the bare pipe and the enclosed pipe is $\Delta L \geq 32$ dB for Sample G, $\Delta L \geq 30$ dB for Sample F and $\Delta L \geq 28$ dB for Sample C.

Samples D and H also reduce the sound pressure levels $L_{\mathrm{Zeq,nT}}$, once the global difference between mean sound pressure levels as calculated for the bare pipe and the enclosed pipe is $\Delta L \geq 23$ dB.

Because of such fact, Samples C, D, F, G and H attain global sound pressure level differences, $L_{\mathrm{Zeq,nT}}$, greater than 20 dB regarding the mean as calculated for the bare and the enclosed pipe. This might represent roughly one quarter change in terms of the sound sensation perceived.

Samples E and I also present considerable reduction regarding sound levels, the global difference between mean sound pressure levels, as calculated for the bare and enclosed pipe is greater than than 10 dB, what might represent roughly a half change in terms of the sound sensation perceived.

In such a case, Sample E does not provide attenuation at frequencies 63 Hz and 125 Hz. Nonetheless, for frequencies between 500 Hz and 8000 Hz, there is a difference greater than 20 dB between mean sound pressure levels as calculated for the bare and the enclosed pipe for each frequency.

In this situation, Sample I also does not show attenuation for frequencies 63 Hz and 125 Hz. Nonetheless, for frequencies between 1000 Hz and 8000 Hz there is a difference greater than 20 dB between mean sound pressure levels sound as calculated for the bare and the enclosed pipe for each frequency.

When comparing the global results for the $L_{\mathrm{Aeq,nT}}$ quantity presented in Table 3 with the limits recommended by the NBR 15575: 2013 standard, one concludes that all samples, with the exception of Samples A and B, meet superior performance levels. The results for the bare pipe and Samples A and B do not meet the values recommended by the standard.

3.3.2. Results from tap opening

The results ($L_{\mathrm{Zeq,nT}}$) may be evaluated and compared regarding the nine samples essayed in Figure 4 and Table 4, due to tap opening.

Samples F, C and H present the best results regarding tap opening; they show considerable reduction for all the frequencies evaluated. The global difference between sound pressure levels, $L_{\mathrm{Zeq,nT}}$, between the mean calculated for the bare and the enclosed pipe, is $\Delta L \geq 14$ dB.

Samples D, E and G also stood out, since they present an global difference greater than 10 dB between the mean sound pressure levels $L_{\mathrm{Zeq,nT}}$, as calculated for the bare and the enclosed pipe; that is, such difference might represent roughly half of the sound volume in terms of perceived sensation.

In this case, regarding tap opening, Samples A and B did present better results when compared to the results due to toilet flushing activation. Nonetheless, these do not show the same performance as compared to the results obtained from other samples due to tap opening.

With respect to Sample A, the global difference $L_{\mathrm{Zeq,nT}}$ between the enclosed tube and the mean calculated for the bare tube is $\Delta L \geq 5$ dB, that is, it might represent a half change in terms of sound sensation. It presents good sound reduction, mainly in the frequency range between 63 to 250 Hz. With respect to Sample B, the global difference $L_{\mathrm{Zeq,nT}}$ between the sound pressure levels and between the mean calculated for the bare and the enclosed tube is $\Delta L \geq 4$ dB. In such a case, Sample I does not provide attenuation for frequencies 63 Hz and 125 Hz. Nonetheless, considering the frequencies between 250 Hz to 2000 Hz, $\Delta L \geq 4$ dB is obtained for each frequency. And $\Delta L \geq 10$ dB for each frequency, between frequencies 4000 Hz to 8000 Hz.

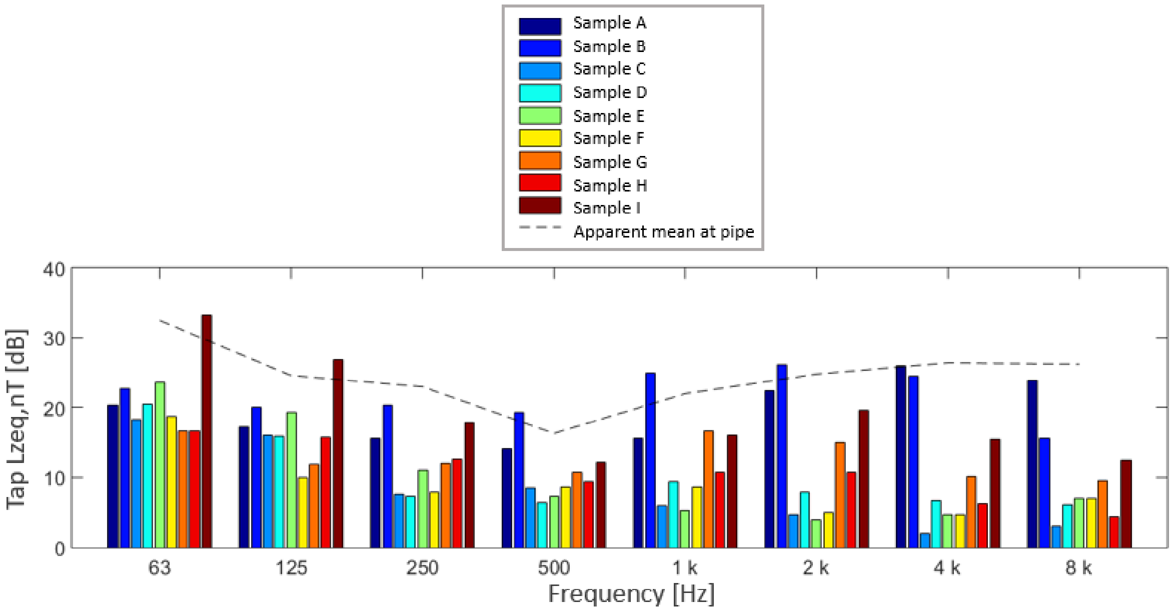

Figure 4: Comparison of $L_{Zeq,nT}$ between essayed samples due to tap opening.

Table 4: Comparison of $L_{Zeq,nT}$ due to tap opening.

Frequency Hz	A	B	C	D	E	F	G	H	I	Bare Pipe
63	20,4	22,8	18,3	20,5	23,7	18,8	16,7	16,6	33,2	32,5
125	17,3	20,1	16,1	15,9	19,3	10,0	11,9	15,8	26,9	24,6
250	15,6	20,3	7,6	7,3	11,0	7,9	12,0	12,7	17,9	23,0
500	14,2	19,3	8,5	6,5	7,3	8,7	10,7	9,4	12,2	16,3
1000	15,7	24,9	6,0	9,4	5,3	8,7	16,6	10,8	16,1	22,0
2000	22,4	26,2	4,7	7,9	4,0	5,0	15,1	10,7	19,6	24,8
4000	26,0	24,5	2,0	6,8	4,6	4,7	10,1	6,3	15,5	26,4
8000	24,0	15,7	3,0	6,1	7,0	7,1	9,6	4,3	12,5	26,2
Global (A)	**30**	**31**	**12**	**15**	**13**	**14**	**21**	**16**	**24**	**32**

When comparing the global results for the $L_{\text{Aeq,nT}}$ quantity presented in Table 4 with the limits recommended by the NBR 15575:2013 standard, it may be concluded that all samples, with the exception of the Sample B, meet superior performance. The results for the bare tube and for the B Sample meet intermediate performance levels.

4. CONCLUSION

From the results presented by this article, it may be concluded that the acoustic solutions evaluated, except for Samples A and B, reduce the noise levels due to toilet flushing activation and manage to meet the superior performance levels from the NBR 15575: 2013 standard regarding the magnitude $L_{\text{Aeq,nT}}$. Samples C, D, F, G and H attain a difference regarding the global sound pressure levels, $L_{\text{Zeq,nT}}$, equal to $\Delta L \geq 20$ dB for the noises originating from toilet flushing activation.

Regarding the noise generated due to tap activation, all the samples, including bare tubing, meet the requirements from the NBR 15575: 2013 standard concerning the magnitude $L_{\text{Aeq,nT}}$. Samples F, C and H respectively present the best results due to tap opening and present considerable sound reduction over all the frequencies evaluated. The global difference $L_{Zeq,nT}$ is $\Delta L \geq 14$ dB. Samples D, E and G also stood out since they present $\Delta L \geq 10$ dB.

Face to this, this work has managed to evaluate and compare acoustic results for nine samples, wherein suppliers' concern over their products' acoustic performance has become clear, their having accepted to take part in this research without hesitation, and keeping clear concern for constantly improving the performance of their products.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] CORRÊA, Aline Perdigâo; DE NIEMEYER, Maria Lygia Alves. Ruído de Tubulação como Fator de Desconforto em Salas de Reunião em Edifício Institucional: Um Estudo de Caso. In: **SBQP 2009**. 2009.

[2] NBR 15575 - Edificações Habitacionais - Desempenho. 2013.

[3] QUERIDO, J.G. Instalações prediais hidráulico sanitárias: prognóstico de ruídos. In: **Tese de Doutorado – Universidade Federal de São Paulo, São Paulo.** 1993.

[4] NBR 5626 - Instalação predial de água fria. 1998.

[5] NBR 7198 - Projeto e execução de instalações prediais de água quente. 1993.

[6] NBR 10844 - Instalações prediais de águas pluviais - Procedimento. 1989.

[7] NBR 8160 - Sistemas prediais de esgoto sanitário. 1999.

[8] PAVANELLO, Lívia Ribeiro et al. Investigação do ruído gerado por instalações hidrossanitárias em uma edificação multifamiliar. In: **Dissertação de Mestrado - Universidade Federal de Santa Maria**. 2014.

[9] ISO 16032 Acoustics - Measurement of sound pressure level from service equipment in buildings - Engineering method. 2004.

[10] ISO 3382-2: Acoustics - Measurement of room acoustic parameters - Part 2: Reverberation time in ordinary rooms. 2008.