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NOISE CONTROL IN A WOOD PROCESSING INDUSTRY ENVIRONMENT THROUGH THE TECHNIQUE OF PARTIAL ENCLOSURE BUILT WITH PARTITIONS DEVELOPED WITH REGIONAL MATERIAL

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Abstract. *The industrialization of wood contributes significantly to the economic development of the northern region. However, consists an activity to the maximum risk as does the Brazilian legislation, having high rates of accidents and occupational diseases, among these risks is included the noise. This paper describes a methodology for evaluating and controlling of environmental noise in industrial wood processing, where it first made the identification of noise sources and its Sound Power Levels by the intensimetry technique and also a pre-investigation to determinate Sound Pressure Levels to assess the occupational noise according to Brazilian rules in force. Subsequently, we created a numerical model by the method of acoustic rays that can faithfully describe the physical phenomena of the environment, using commercial software Odeon Room Acoustics. The results pointed to the need for construction of partial enclosure to the sound sources of environment, which was carried out using partitions developed with regional material of good performance, as attested in the training trial, which demonstrated the effectiveness of action by the numerical model.*

Keywords: *enclosure, regional material, noise control, acoustic modeling.*

1. INTRODUCTION

The Brazilian Amazon is one of the main wood producing regions of the world, behind only Malaysia and Indonesia (OIMT, 2006). Among the activities developed in the Amazon states, the wood industry is one of the most important sectors of their economy. Just in 2000, Pará generated approximately $ 1 billion of income. The activities of wood industrialization contribute significantly to the economic development of the Northern Region of Brazil, with occupancy of labor and profits derived from exports to the national and foreign market. Even generating large numbers of jobs, is an activity that has maximum risk, therefore, it has a high rate of accidents and diseases related with the job.

Among these risks is the occupational noise. The noise, or unwanted sound, as a type of damage to the human body is not fatal, but it can influence directly the quality of life of affected individuals. The negative consequences caused by noise to the humans, both pathological and psycho-emotional, have been proven scientifically and reviewed in scientific

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literature during the last 20 years. The noise is an agent that damages the natural and ecological balance, causing the exposed people become stressed and suffer hearing loss induced by the noise. A sound pressure level between 55 and 65 dB (A) is capable of maintaining the body in a state of alert, causing the person to feel difficultly to relax and pay attention. From 65 dB (A) it begins the gradual stress with the biochemical imbalance, increasing the risk of heart attack, stroke, infections, osteoporosis, etc. 100 dB (A) can already cause immediate hearing loss.

Given the importance of the forestry sector in the economy of the Amazon, the present work aims to study a possible form of noise control in this type of environment, seeking to make them salubrious job environments. Thus, the study is done using the acoustic modeling using numerical methods. Besides studying the control of noise, it is also done a brief analysis of the occupational noise that a worker is exposed in the wood industry, checking the sound pressure levels at the site. This research also makes a study of alternative materials for use in enclosure. These materials are inexpensive and easy to access in the region. They are partitions made with plywood, coconut fiber and sawdust. These are easy to manufacture and can be manufactured using equipment normally found in a wood industry. Figure 1 shows the enterprise and the place where the measurements were made.

Figure 1. (a) Enterprise where made the study; (b) Place where made the measurements.

2. ACOUSTIC MODELING

The methods of computer aided simulation performed, in recent years, as the most powerful tool in predicting the acoustic field in environments, especially those methods based on acoustic ray and source image. These methods, with their various derivations, are the basis for the creation of algorithms and computer programs. In this work, we used the software Odeon, which functions as a combination of these two methods of analysis.

At the method of the source image, virtual mirror sources are created from the environment organization, illustrated in Figure 2 (a). This method has low computational cost since it is based on a simple theory, but it is not as effective in rooms with multiple or irregular objects scattered, requiring visibility test, shown in Figure 2 (b).

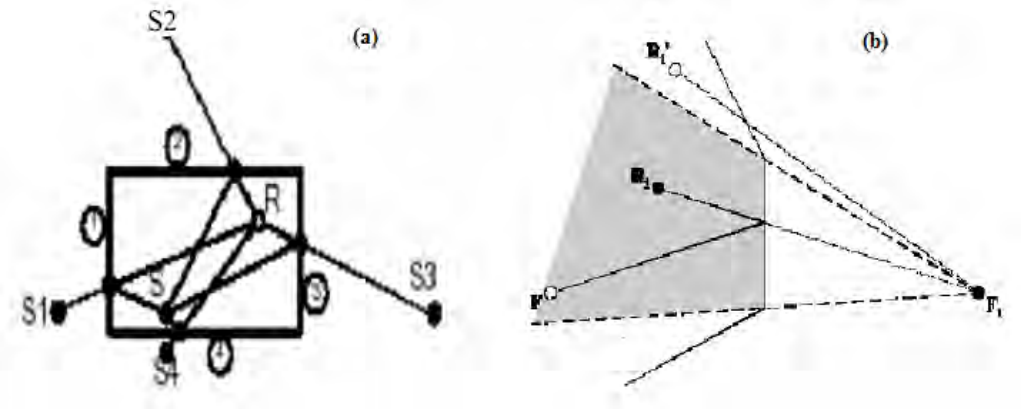

Figure 2. (a) Method of source image; (b) Visibility test to not rectangular rooms by Toro (2005).

The method of acoustic rays or ray tracing, shown in Fig., is based on the energy emitted by the source turning into a discrete number of rays. The energy of each ray is defined as the energy emitted by the source divided by the number

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of rays. The speed of each ray is equal to the speed of sound until colliding with any surface inside. It takes into account the energy loss caused by reflection and absorption of sound. The ray travels up that does not have a significant level of energy when starting a new section of rays.

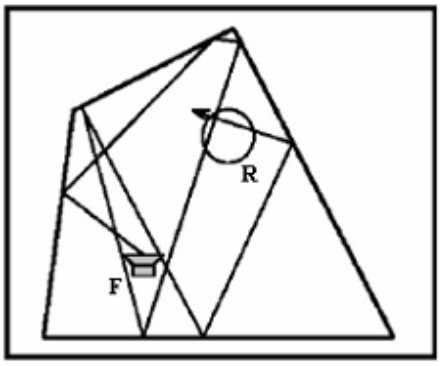

Figure 3. Method of ray acoustic, from sound source (F) to the receiver (R), by Raynoise (1993).

2.1. Virtual Model

For the construction of the model, firstly, it is generated three-dimensional sketch of the environment and objects of interest using CAD platform or even the software Odeon, being that the measures and positions in the model should be as close to actual size. So, this time, at the Odeon necessarily, it must insert the environmental characteristics in the model, including sound power levels of noise sources, the various materials and surfaces, etc. So, for analysis, virtual microphones are modeled, that capture all information transmitted by the rays, enabling the calculation of the sound pressure level at certain points. Although we can not say that all rays are captured by the microphone or that the microphone does not capture rays of false reflections, this method has the advantage of including curved surfaces and scattering as well as being very quick. The model generated in this work is shown in Fig 4.

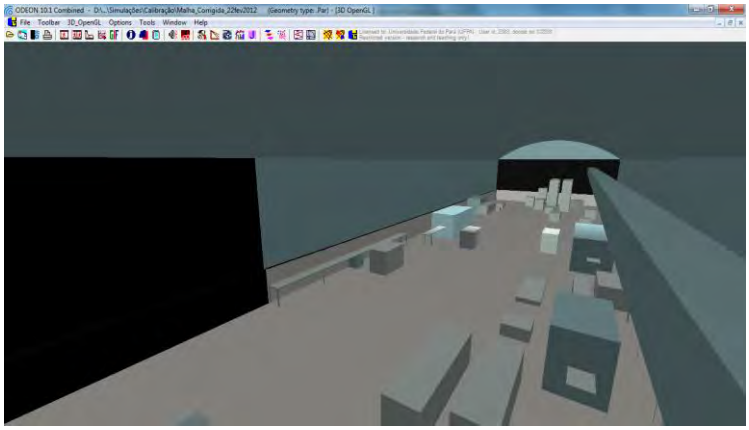

Figure 4. Model generated in software Odeon (2011).

3. MEASUREMENTS IN REAL ENVIRONMENT

For the generation and validation of the model is necessary to perform measurements in the studied environment. Besides geometrical measurements, it is necessary to measure the sound power level of the machines identified as noise sources. It is also necessary to make measurements of sound pressure level at certain points of the environment, the same as the virtual microphones shown in Fig 5.

The sound pressure level is the physical measurement preferred to characterize the subjective sense of the intensity of the sounds, and it is the magnitude more relevant when the objective is to assess the danger and disturbance caused by noise sources in the environment. In the virtual model the microphones are configured in the same spots where the microphones are located during the measurements, because, when comparing the results of these measurements with the virtual microphones, it is possible to calibrate the numerical model. Once the model is calibrated, we can predict, virtually, the results obtained for possible solutions for noise control.

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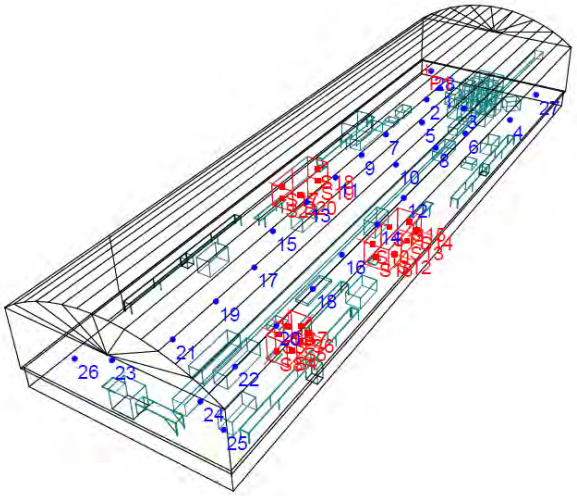

Figure 5. Model generated in software Odeon with the positions of the virtual microphones (2011).

These results were also used to feed a computer routine that implements triangular interpolation based on a linear interpolation, presenting in Matlab Toolbox ™. This routine takes as input SPL values of each measuring point and its coordinates relative to a fixed origin. Subsequently, we set a rectangular grid of points, with uniform distribution, which is limited by the coordinates of the measuring points. The values are interpolated throughout the network, from the results for SPL of each measuring point. The drawback of this method is to not allow discontinuities in the map as walls, columns, equipment, and other objects and features of the environment studied. However, this methodology is sufficient to perform an analysis of occupational noise, one of the objectives of this work. Thus, it is obtained an acoustic map of the environment, seen in Fig. 6, which is done through a diagnosis of occupational noise, based on the Brazilian laws and regulations.

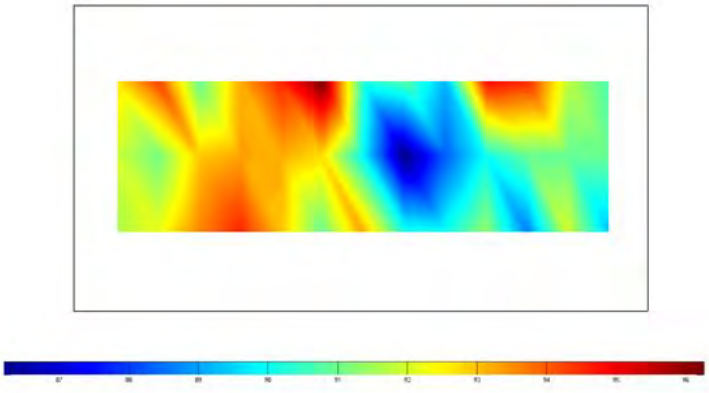

Figure 6. Acoustic map generated by computational routine implemented at MATLAB, showing values of SPL in dB(A) (2011).

The sound power level is an intrinsic characteristic of the source, not being influenced by the acoustic characteristics of indoor or outdoor (Bistafa, 2006; Brito, 2006; Gerges, 2000). From SWL results, it is possible to calculate the sound pressure level in any environment size, shape and absorption coefficient of the surfaces, providing better prediction and control of noise propagation in the environment. Once obtained the values of sound power levels, these are added to the virtual model.

The sound power measurements of the main noise sources were performed using the technique of sound intensity and followed the recommendations of ISO 9614-1 (1993) and ISO 9614-2 (1996), using the measurement methodology for scanning.

The equipment used in these measurements are shown in Figure 7. These were: Brüel & Kjaer Sound Pressure Level Meter, type 2238 - Mediator, Brüel & Kjaer Sound Intensity Probe, type 3595, Brüel & Kjaer Sound Intensity Probe Calibrator, type 4297, Brüel & Kjaer Sound Pressure Level Meter, type 2236 - Investigator.

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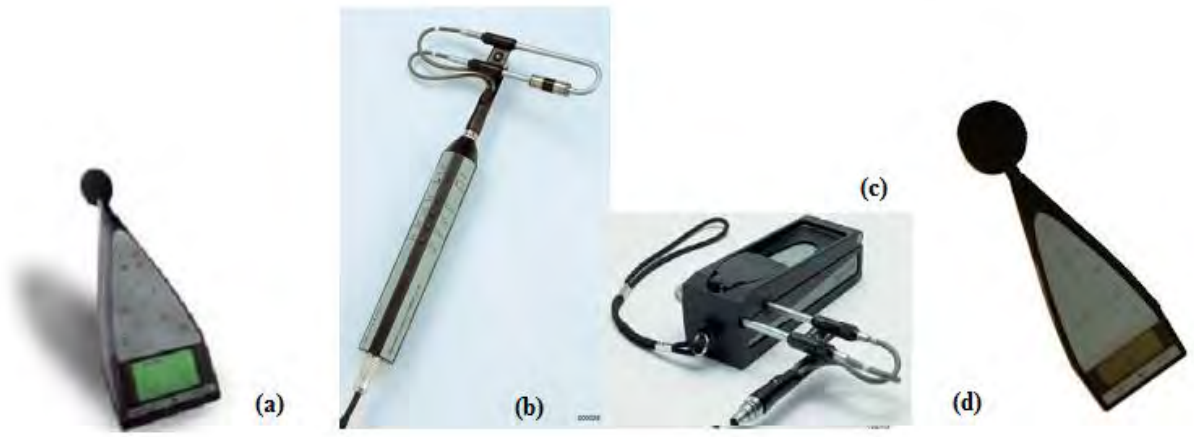

Figure 7. (a) Mediator; (b) Sound Intensity Probe; (c) Sound Intensity Probe Calibrator; (d) Investigator. (2010)

4. COMPARISON BETWEEN REAL AND VIRTUAL RESULTS: A VALIDATION OF VIRTUAL MODEL

Comparing the experimental SPL results with those provided by the numerical model environment studied, with sound sources properly assigned, it is observed that the model was able to reproduce the overall trend of the experimental results, as can be seen in Table 1.

Table 1. Comparison between real and virtual results in dB(A) (2011).

Microphone	Experimental	Virtual	Diference	Microphone	Experimental	Virtual	Diferece
1	91,8	89,6	2,2	15	92,0	93,8	1,8
2	92,8	90,5	2,3	16	92,8	93,7	0,9
3	91,6	91,4	0,2	17	90,8	93,0	2,2
4	91,9	89,8	2,1	18	91,3	92,7	1,4
5	90,7	92,0	1,3	19	91,2	92,1	0,9
6	92,6	91,4	1,2	20	92,3	93,7	1,4
7	92,8	92,7	0,1	21	91,3	91,1	0,2
8	92,7	92,5	0,2	22	90,4	91,6	1,2
9	93,7	94,3	0,6	23	90,8	89,6	1,2
10	93,1	93,1	0,0	24	91,7	90,3	1,4
11	94,0	93,5	0,5	25	89,9	89,3	0,6
12	90,2	92,9	2,7	26	90,9	88,4	2,5
13	93,7	94,2	0,5	27	85,9	87,7	1,8
14	91,2	93,6	2,4	28	85,8	87,9	2,1
Global Value	91,4	91,7	0,2				

5. ANALYSIS OF OCCUPATIONAL NOISE BY BRAZILIAN LAW

It is customary to divide the effects of noise on human into two parts: those who work on the health and well being and the effects on hearing. Brazilian law just recognizes the effects of noise on hearing; these effects can be divided into 3 phases: temporary change in hearing threshold, permanent change in hearing threshold and acoustic trauma.

To damage hearing is necessary that the worker be exposed to high noise levels or sound pressure. Studies show that exposure to noise with values above 85 decibels, which is the case of workers who job in the environment analyzed, is harmful to the human ear, depending on the time the worker is exposed.

With a higher noise level, the time that the worker is exposed is reduced. In Tab. 2, values of noise and maximum time allowable daily exposure are shown, as Annex No. 1 of the NR-15 - Standard 15 of the Brazilian Ministry of Labour and Employment.

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Table 2. Maximum daily exposure, second the NR-15 (2011).

SPL dB(A)	Permissible Time	SPL dB(A)	Permissible Time
85	8 hours	98	1 hour e 15 minutes
86	7 hours	100	1 hour
87	6 hours	102	45 minutes
88	5 hours	104	35 minutes
89	4 hours e 30 minutes	105	30 minutes
90	4 horas	106	25 minutes
91	3 hours e 30 minutes	108	20 minutes
92	3 horas	110	15 minutes
93	2 hours e 40 minutes	112	10 minutes
94	2 hours e 15 minutes	114	8 minutes
95	2 horas	115	7 minutes
96	1 hour e 45 minutes		

As NR 15, to the values founded in the noise level will be considered the maximum allowable daily exposure on the immediate higher level. If NR 15 if nr 15 being severely followed, a worker could not spend more than 3 hours and 30 minutes in the environment. Generally, the workday in this type of company is 8 hours, which exceeds so much the limits of the standard. Even if it was taken as reference the lowest measured value of SPL, the limits of the standard already are exceeded.

The actual Brazilian previdence legislation (INSS) was established by Laws 8212 and 8213 of 1991, as amended by Laws 9.032/95 and 9.528/97 and regulated by Decree 3048 of May 6, 1999. In these, in its Annex II List A, the noise is included among harmful agents to health, whose exposure may determine the occurrence of labor disease. The Annex III of Decree 3048 of May 6, 1999, establishes the conditions to which the employee is entitled to receive compensation in the form of aid, accident, repeating with discrete advances, the previous regulations of 1991. In case of inspection, the company would be penalized, and may suffer a lot of damage with fines, compensation and so on and other disorders.

To preserve the hearing of workers or preventing its deterioration, it is necessary to implant, in the company, a number of procedures that can be styled in Hearing Conservation Program (PCA). After performing assessments, it should be taken providences to reduce noise generation and prevent worker exposure to noise.

Control actions can be taken in making an action on the noise emitting source, for example, deletion or substitution of noisy machine by quieter machine, change in the rate of operation of the machine, reducing the distance and increasing the concentration of the machine; intervention on the propagation of noise as brackets anti vibrations, full or partial enclosure, barriers, silencers and treatment with sound absorber material; intervention on the worker as quiet cabin insulation, reducing the exposure time and use of Personal Protective Equipment (PPE).

As already mentioned, this study analyze virtually the enclosure of machines considered as major sources of noise. As this enclosure is made with partitions made with alternative materials, will first be explained about these partitions, and will be explained later the results of noise control.

6. PARTITIONS MADE WITH ALTERNATIVE MATERIALS

The partitions were developed in Group of Vibration and Acoustics of Federal University of Pará (GVA). When they thought, the idea was conceived, with easy and low cost, partitions that have good performance when used in acoustic isolation. It consists of two plywood boards of 10 mm thickness with a 50mm space between them, this space can be filled or not, according to the schematic in Figure 8. The filling is with coconut fibber or sawdust and its construction is very simple and can be done, usually, in the company where they will be used.

Figura 8. Scheme of the Partitions.

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We must know the sound transmission loss of these partitions because these data are used to feed the computational model, at the study of the alternative noise control. The measurement of this data collection occurred using small reverberant chambers, which were built on the laboratory of GVA, in accordance with international standards, specifically ISO 140 and ISO 354. Its dimensions were established from the application of a scale of 1:6 on the UFSM chamber dimensions, with some adaptations. The efficiency of these mini cameras was proven by Aviz (2006) in his master researcher. Figure 9 shows a schematic of the study of transmission loss of the partitions.

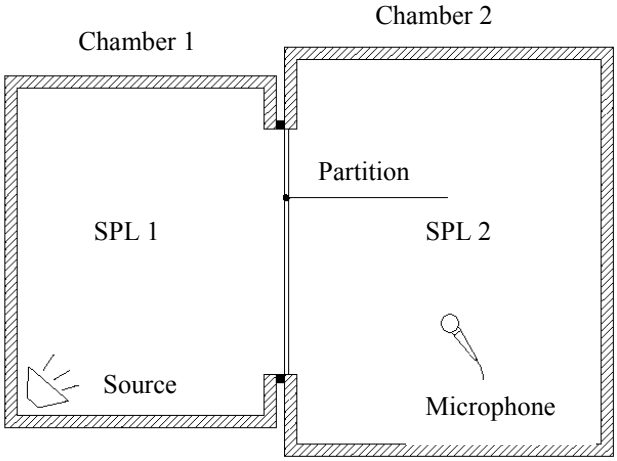

Figure 9. Scheme of the transmission loss measurement.

The measurements were performed according to ISO 140 (1997) and the obtained results for the differents partitions are shown in Tab. 3. As we can see, the partition that had the best result, at the most number of frequency bands was the sawdust, justifying its using in this work.

We used were B&K microphones, model 4942-021-A of 2679197 series, connected to the signal analyzer Pulse B&K and configured with the aid of a computer. Since the signal from the power source is very small, we used a B&K signal amplifier, type 2716, as shown in Fig. 10.

Table 3. Sound transmission loss with each partition in dB(A).

Partition	125 Hz	250 Hz	500 Hz	1 KHz	2 KHz	4 KHz	8 KHz
Coconut Fiber	29,9	30,7	34,3	29,1	27,7	41,8	54,4
Compacted Coconut Fiber	30,3	18,7	39,3	33,7	31,7	45,9	54,5
Sawdust	37,5	31,7	38,2	31,7	28,7	40,1	53,3
Compacted Sawdust	40,3	31,5	30,6	27,4	32,3	43,3	42,2
Empty Partition	30,0	25,8	38,5	31,9	29,8	33,6	49,6

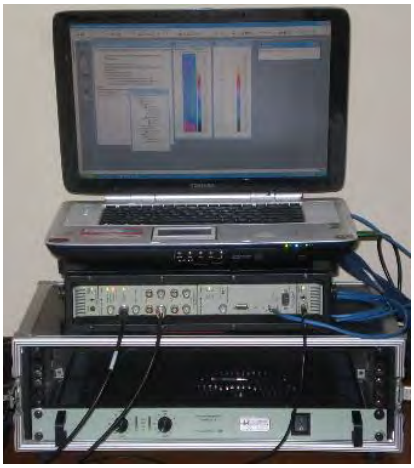

Figure 10. Equipments used to the loss transmissions measurements.

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7. VIRTUAL STUDY OF NOISE CONTROL

As described above, the noise control solution was thought with a trajectory intervention, because the other two alternatives, on the source (machinery) and on the receiver (workers), are unviable, from the point of requiring high investments and awareness regarding the use, respectively. Therefore, the use of partitions, which measured in the laboratory, was observed as great alternatives. Other justification is the fact that they are made with low cost materials.

Thus, virtually, we done a project of enclosing on the machines considered as main noise sources and the constituent materials of these partitions assigned the values of transmission loss measured in the laboratory, how listed in Tab. 3. So, with the model calibrated, the results of changes in geometry, that in this case is the use of partitions as shown in Figure 11, can be considered reliable.

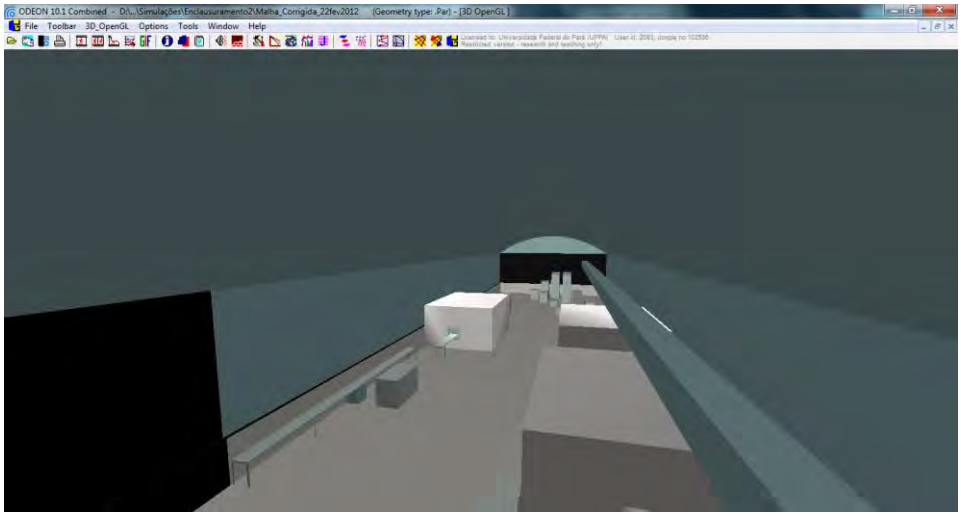

Figure 11. Virtual Solution.

8. CONCLUSION

From the simulation, the results were listed in Tab. 4. These justify the proposed solution to the problems found in the area of the company. It is worth mentioning that to analyze the results shown should understand column 'Difference' as a close representation of the reduction of sound pressure levels in the environment. The results are considered as a close representation, because of all the simplifying assumptions used, since the construction of the model until the characteristics of the constituent elements of this.

Table 4. Enclousures results in dB(A).

Microphone	Experimental	Enclousure	Diference	Microphone	Experimental	Enclousure	Diference
1	91,8	83,4	8,4	15	92,0	88,3	3,7
2	92,8	84,2	8,6	16	92,8	87,1	5,7
3	91,6	85,5	6,1	17	90,8	86,9	3,9
4	91,9	83,3	8,6	18	91,3	87	4,3
5	90,7	85,6	5,1	19	91,2	86,1	5,1
6	92,6	84,9	7,7	20	92,3	87	5,3
7	92,8	86,8	6,0	21	91,3	85,3	6
8	92,7	85,6	7,1	22	90,4	85,7	5,7
9	93,7	87,3	6,4	23	90,8	83,8	7
10	93,1	86	7,1	24	91,7	84,3	7,4
11	94,0	85,5	8,5	25	89,9	83,4	6,5
12	90,2	85,9	4,3	26	90,9	82,4	8,5
13	93,7	86,1	7,6	27	85,9	80,9	5
14	91,2	86	5,2	28	85,8	82	3,8
Global	91,4	85,2	6,2				

The values found in Tab. 4 show that the environment, almost in its entirety, would become salubrious second national standards. Emphasize that the results are not considered accurate for human sensations in this environment, for

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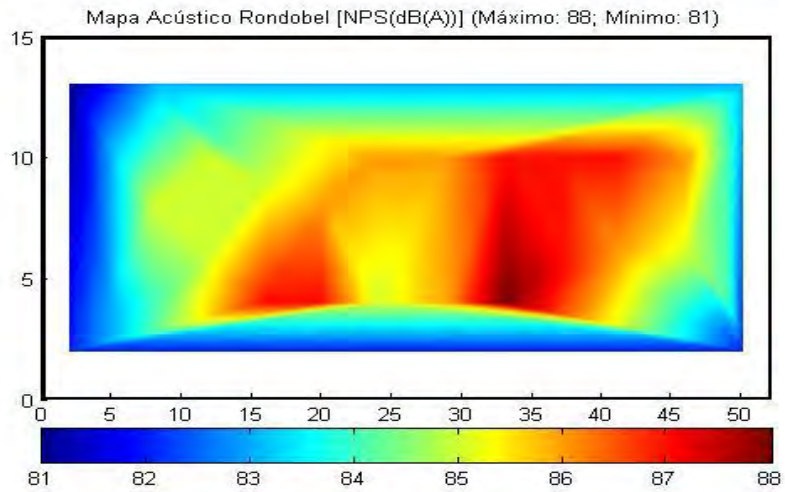
not taking note that, together with the enclosure of the machines, there are the use of PPE by receptors (workers). Thus, given the fact that the model has a tendency of behavior very close to the real environment, we can say that the use of alternative materials partitions is a viable solution, to the operational question, taking into account their implementation and to the economic point of view, considering that its construction is with low cost materials. An approximation to the situation after the enclosure is shown in Figure 12.



9. REFERENCES

Bistafa, S.R., 2006, "Acústica Aplicada ao Controle de Ruído", Ed. Edgard Blücher, São Paulo, Brasil.

Cardoso, Helder Fábio Santos, 2008, "Desenvolvimento de Enclausuramento Parcial Através de Métodos Numéricos para Controle de Ruído de Grupo Geradores em uma Usina Termoelétrica da Eletronorte", Trabalho de Conclusão de Curso, Faculdade de Engenharia Mecânica, Universidade Federal do Pará, Belém, Brasil.

Cardoso, Helder Fábio Santos, 2010, "Soluções numéricas de controle de ruído em usinas hidrelétricas da CHESF", Dissertação (mestrado) – Universidade Federal do Pará, Instituto de tecnologia, Programa de Pós-Graduação em Engenharia Mecânica, Belém, Brasil.

Gerges, Samir N. Y. , 2000, "Ruído: Fundamentos e controle. 2. ed.", . NR Editora, Florianópolis, Brasil.

Guedes, Reginaldo C., 2007, "Projeto e Construção de Uma Câmara Reverberante em Escala Reduzida para a Caracterização Acústica de Materiais Absorventes", Dissertação (Mestrado em Engenharia Mecânica) – Coordenação do Programa de Pós-Graduação em Engenharia Mecânica, Universidade Federal do Pará, Belém, Brasil.

Mello Júnior, Paulo Roberto Moretzsohn de, 1998, "O Ruído Industrial e Sua Regulamentação Nacional e Internacional", Encontro Nacional de Engenharia de Produção.

Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Ações Programáticas Estratégicas, 2006, "Perda Auditiva Induzida Por Ruído (Pair)", Saúde do Trabalhador: Protocolos De Complexidade Diferenciada 5. Série A. Normas E Manuais Técnicos. Ed. Do Ministério Da Saúde. Brasília, Brasil.

NBR-10151. Acústica, 2000, "Avaliação do ruído em áreas habitadas, visando o conforto da comunidade – Procedimento", Associação Brasileira de Normas Técnicas.

NR-15. "Atividades e operação insalubres". Norma Regulamentadora, Ministério do Trabalho e Emprego.

Odeon ver 10 Combined, 2009, "User Manual", Bruel & Kjaer, Dinamarca.

Serviço Florestal Brasileiro, 2010, "A Atividade Madeireira na Amazônia Brasileira: produção, receita e mercados",

Vieira, R.J.A., 2008, "Desenvolvimento de Painéis Confeccionados a Partir de Fibras de Coco para Controle Acústico de Recintos", Dissertação de Mestrado, Universidade Federal do Pará, Belém, Brasil.

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