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EXPERIMENTAL STUDY ON THE USE OF THE PLANT AS ATTENUATOR IN THE SOUND INDUSTRIAL POLLUTION

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Abstract: *The paper presents an experimentally study, on the use the plant over the pollution as a sound attenuator. Are studying a system of six decorative plants, planted in individual pots arranged on a metal rack in front of a source of pollution, and multi-purpose ventilation that work to two industrial buildings of the printing materials factory for food industry. This paper is part of a study regarding the assessment of noise pollution in industrial activity.*
Key words: *experimental study, vegetable sound attenuation, industrial pollution.*

1. INTRODUCTION

The paper describes an experimental study which seeks to put in evidence how the plants with pleated sheet, planted in individual pots, reduce pollution, outside industrial halls.

1.1. Objective to Assess

It is believed a ventilation system multi-bodies, which is found in the inner courtyard of a factory used to printed materials for the food industry. This ventilation station serves two industrial buildings. The nearest Hall, is located at 1.5 m from the station. The situation presents itself as in Figure 1.

Fig. 1. Venting station-panoramic image

The area in which the measurements were made, labeled "x" red, was considered the center of the acoustic source, because by listening around the source, here was the prevailing sound level, according to the standard [1] and sounds around negligible.

The measurements were made at 1 m from the center of the acoustic source and at a height of 1.5 m, at the human ear, according to the standard [1] (fig. 2).

Fig. 2. Centre of acoustic source (red star)

1.2. Measurement device NL-32

Measurement was made with sound-level meter type NL-32 produced by RION society from Japan. It is a portable device used for sound level measurements accepted in Romanian standards and of the IEC standards.

Taking into account the following sizes measured:

• continuous equivalent sound level (L_{eq})-equivalent sound pressure within 1 min;

• the level of exposure of the sound (L_E)-absolute sound pressure equivalent to 1 minute interval;

• maximum level of sound (L_{max})-maximum sound pressure within 1 min;

• minimum level of the sound (L_{min})-minimum sound pressure within 1 min;

• sound level equivalent (L_{Ceq})-equivalent sound pressure "C"-that is perceptible by the human ear, within 1 minute.

A minute have been conducted six measurements, which were succeeded by an interval of 10 seconds.

1.3. User plane

Evaluation of attenuation of noise pollution caused by the source of the noise-blowing station (fig. 1), was made in the following steps:

1. It was measured for each species of plant: height, weight and diameter of pots and plants contained in them;
2. It has measured the noise source, with no plants system;
3. It was fitted to the stand;
4. It has designed every delivery groupage from six categories of plants considered absorbent [2], [3];
5. Measurements were made of noise in front stand with each grouping of plants;
6. Measurements were made of noise behind the stand with each grouping of plants.

2. SYSTEM OF PLANTS

Plant system of sound absorbing pollution were:

- ✓ Buxus sempervirens;
- ✓ Thuja occidentalis variant „Smaragd";
- ✓ Ficus benjamina;
- ✓ Spatiphyllum wallisii;
- ✓ Heptapleurum arboricola – Schefflera;
- ✓ Philodendron scadens.

The six species of plants were arranged on a metal rack for 1.5 m x 1 m x 1 m, so that the height of 1.50 m at which measurements were made, the plants look like a green wall.

2.1. Plant characteristics and assembly

Buxus sempervirens (noted B) has the characteristisc: diameter 48cm; plant height 42 cm; the height of the plant with pot 72cm.

Thuja occidentalis variant „Smaragd" (noted T) has the characteristisc: diameter 42cm; plant height 140 cm; the height of the plant with pot 170cm.

Ficus benjamina (noted F) has the characteristisc: diameter 70cm; plant height 144 cm; the height of the plant with pot 166cm.

Spatiphyllum wallisii (noted S) has the characteristisc into two different dimentions:

- ➢ higher plant: diameter 80cm; plant height 60 cm; the height of the plant with pot 80cm, plant number 2 pieces;
- ➢ smaller plant: diameter 40cm; plant height 40 cm; the height of the plant with pot 55cm, plant number 2 pieces.

Heptapleurum arboricola – Schefflera (noted H) has the characteristisc: diameter 40cm; plant height 116 cm; the height of the plant with pot 136cm.

Philodendron scadens (noted P) has the characteristisc: diameter 30cm; plant height 24 cm; the height of the plant with pot 34cm.

With the six species of plants were made the seven assemblies as the follow in the next seven figures.

First assembly is formed in front with two Buxus sempervirens, and in the back with four Thuja occidentalis variant „Smaragd" (fig. 3).

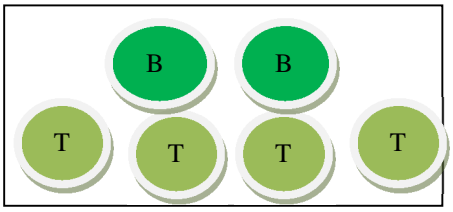


Fig. 3. Assembly of Two Buxus (B) + Four Thuja (T)

Second assembly is formed with four Thuja occidentalis variant „Smaragd" (fig. 4).

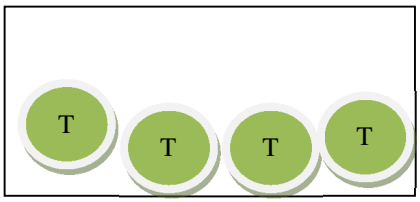


Fig. 4. Assembly of Four Thuja (T)

Third assembly is formed with two Buxus sempervirens (fig. 5).

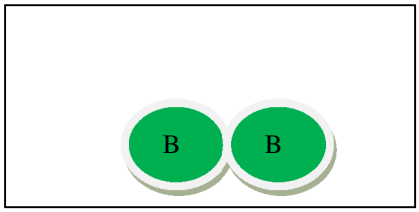


Fig. 5. Assembly of Two Buxus (B)

Fourth assembly is formed with two Ficus benjamina + Ficus benjamina variegata (fig. 6).

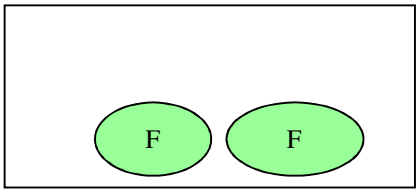


Fig. 6. Assembly of Two Ficus (F)

Fifth assembly is formed in front with three smaller Spatiphyllum wallisii, and in the back with two higher Spatiphyllum wallisii can be see in Figure 7.

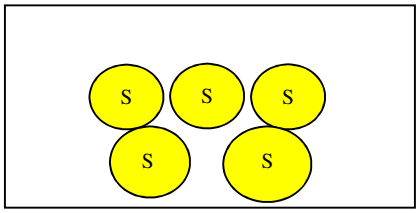


Fig. 7. Assembly of Five Spatiphyllum (S)

Sixth assembly is formed with four Heptapleurum arboricola – Schefflera (H) is given in Figure 8.

Seventh assembly is formed with five Philodendron scadens (fig. 9).

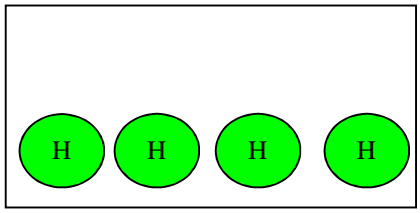


Fig. 8. Assembly of Four Heptapleurum

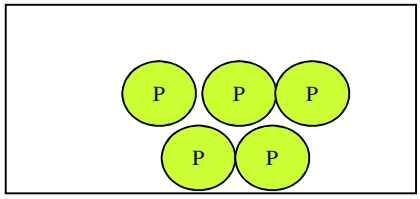


Fig. 9. Assembly of Five Philodendron

3. NOISE MEASUREMENTS

Measurements made with sound level meter NL-32, are presented for all specified sizes, which are plotted.

Measurements have been carried out:

- No plant (recorded with the blue color);
- In front of the plant arrangement (recorded with red color);
- Behind the arrangement of plants (registered with the green color).

3.1. Sound Pollution no Plants

The measurement of sound pollution given by the ventilation system is concetreted in the Table 1. The time of measurement is 5/16/2016, at 15:40 in 10 sec.

Table 1.
Measurement of Sound Pollution without Plants

No.	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	81.2	91.2	82.1	80.4	78.2
2.	81	91	81.6	80.2	77.9
3.	81.2	91.2	82	80.1	77.8
4.	81.7	91.7	82.6	80.8	77.8
5.	81.2	91.2	82	80.1	77.8
6.	81.7	91.7	82.6	80.8	77.8

3.2. Sound Pollution with Plants

The assembly of plants are formed as they are given in the Figures 3, 4, 5, 6, 7, 8, and 9. The measurement are situated in the followings tabels.

3.2.1. Buxus Sempervirens + Thuja Occidentalis Var. „Smaragd”

There are two measurements for this arrangement, first in front of this (table 2 – red, noted bt), second in back of this (table 3 – green, noted
BT).

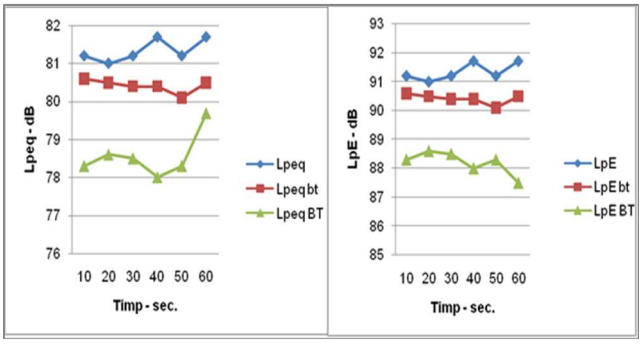
Table 2.
In front of Buxus Sempervirens and Thuja – noted bt

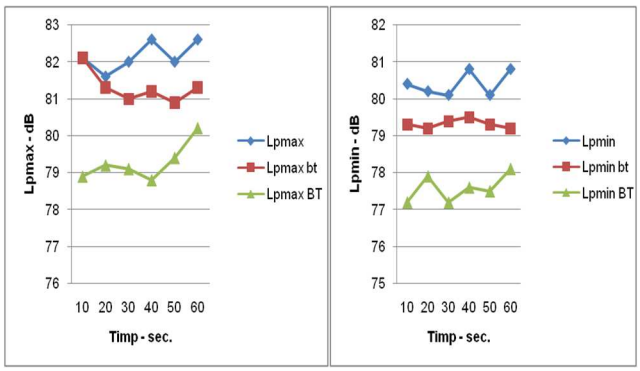
No.bt	Lpeq	LpE	Lpmax	Lpmin	Lceq
1.	80.6	90.6	82.1	79.3	76.9
2.	80.5	90.5	81.3	79.2	76.8
3.	80.4	90.4	81	79.4	77
4.	80.4	90.4	81.2	79.5	77
5.	80.1	90.1	80.9	79.3	76.7
6.	80.5	90.5	81.3	79.2	76.9

Table 3.
Behind of Buxus Sempervirens and Thuja – noted BT

No.BT	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78.3	88.3	78.9	77.2	76.1
2.	78.6	88.6	79.2	77.9	76.2
3.	78.5	88.5	79.1	77.2	76
4.	78	88	78.8	77.6	75.8
5.	78.3	88.3	79.4	77.5	76
6.	79.7	87.5	80.2	78.1	78.1

For a good understanding, the measurements of the Buxus Sempervirens and Thuja arrangement are printed in graphical representations (fig. 10).





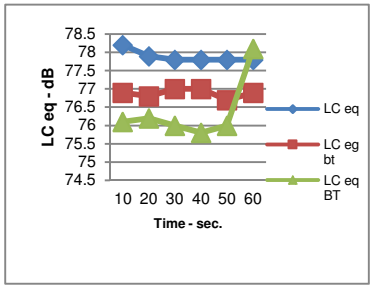


Fig. 10. Measurement of Buxus and Thuja Arrangement

The Figure 10 demonstrated that the sound pollution diminishes with 3 dB (A) until 4.5 dB(A) using as the absorbent plants the combination formed Buxus Sempervirens + Thuja Occidentalis Var. „Smaragd” behind the arrangement.

3.2.2. Thuja Occidentalis Var. „Smaragd”

There are two measurements for this arrangement, first in front of this (table 4 – red, noted t), second in back of this (table 5 – green, noted T).

Table 4.
In front of Thuja – noted t

No.t	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	79.4	89.4	80.4	78.4	76.2
2.	79.4	89.4	80	78.5	76.2
3.	79.2	89.2	80.7	77.8	76.1
4.	79.2	89.2	79.9	78.4	76.2
5.	79.3	89.3	80.1	78.3	76.1
6.	79.3	89.3	80.1	78.3	76.1

Table 5.
Behind of Thuja – noted T

No.T	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78.3	88.3	78.9	77.2	76.1
2.	78.6	88.6	79.2	77.9	76.2
3.	78.5	88.5	79.1	77.2	76
4.	78	88	78.8	77.6	75.8
5.	78.3	88.3	79.4	77.5	76
6.	79.7	87.5	80.2	78.1	78.1

For a good understanding, the measurements of the Thuja arrangement are printed in graphical representations (fig. 11).

The Figure 11 demonstrated that the sound pollution diminishes with 3 dB (A) until 4.5 dB(A) using as the absorbent plants the combination formed Thuja Occidentalis Var. „Smaragd” behind the arrangement.

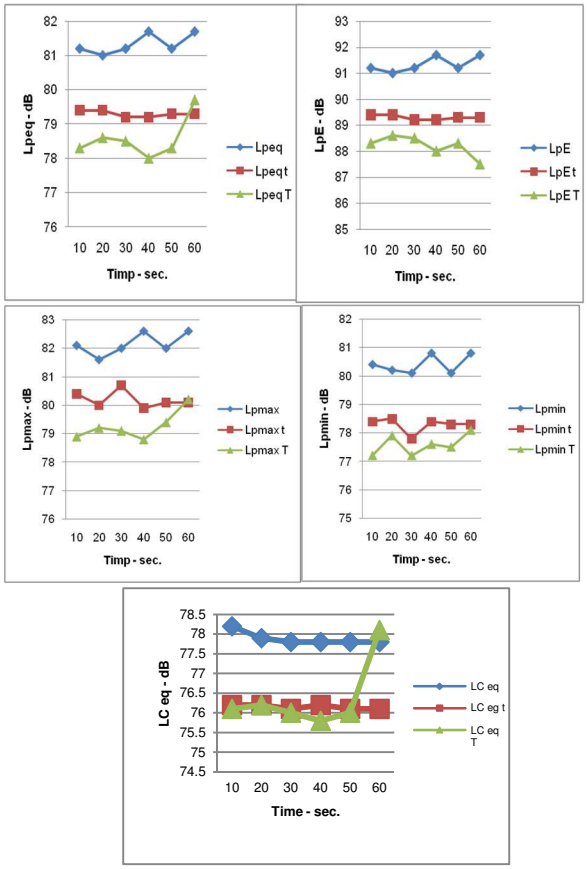


Fig. 11. Arrangement of Thuja „Smaragd"

3.2.3. Buxus Sempervirens Arrangement

There are two measurements for this arrangement, first in front of this (table 6 – red, noted b), second in back of this (table 7 – green, noted B).

Table 6.

In front of Buxus – noted b

No.b	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	80	90	82.2	78.4	76.3
2.	80.3	90.3	81.3	78.8	76.5
3.	79.6	89.6	80.9	78.8	76
4.	79.4	89.4	80.2	78.4	76.2
5.	79.8	89.8	80.5	79	76.4
6.	79.3	89.3	80	78.4	76

Table 7.

Behind of Buxus – noted b

No.B	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78.8	88.8	79.2	78.2	76.5
2.	78.9	88.9	79.6	77.8	76.6
3.	78.7	88.7	79.6	77.9	76.4
4.	78.3	88.3	78.9	77.4	76.2
5.	78.4	88.4	79	77.9	76.1
6.	78.9	86.7	79.6	78.1	76.5

For a good understanding, the measurements of the Buxus arrangement are printed in graphical representations (fig. 12).

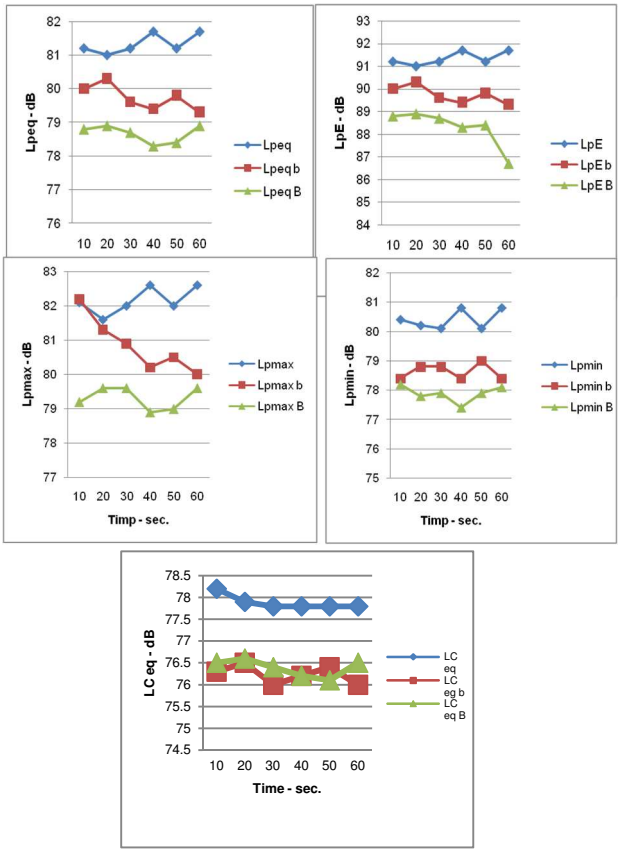


Fig. 12. Arrangement of Buxus

The Figure 12 demonstrated that the sound pollution diminishes with 2 dB (A) until 3.4 dB(A) using as the absorbent plants the combination formed Buxus Sempervirens behind the arrangement. That means Buxus is not enougt good as an absorbent plant.

3.2.4. Ficus benjamina + Ficus benjamina variegata

The assembly of them is in the figure 6, and there are two measurements for this arrangement, first in front of this (table 8 – red, noted f), second in back of this (table 9 – green, noted F).

Table 8.

In front of Ficus – noted f

No.f	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	79.4	89.4	80.6	78.5	76
2.	79.3	89.3	80.1	78.2	75.9
3.	79.2	89.2	80.3	78.2	76
4.	79.5	89.5	80.8	78.5	75.9
5.	79.2	87	80.1	78.6	75.6

6.	79.2	87	80.1	78.6	75.6

Table 9.

Behind of Ficus – noted F

No.F	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78	88	78.4	77.1	75.5
2.	79.3	89.3	80.1	77.6	76
3.	79.4	89.4	80.8	77.8	76
4.	79.8	89.8	81.7	78.4	77.2
5.	78.4	88.4	81	77.9	76
6.	78.6	87.6	78.9	77.7	76.1

For a good understanding, the five measurements of the Ficus arrangement are printed in graphical representations (fig. 13).

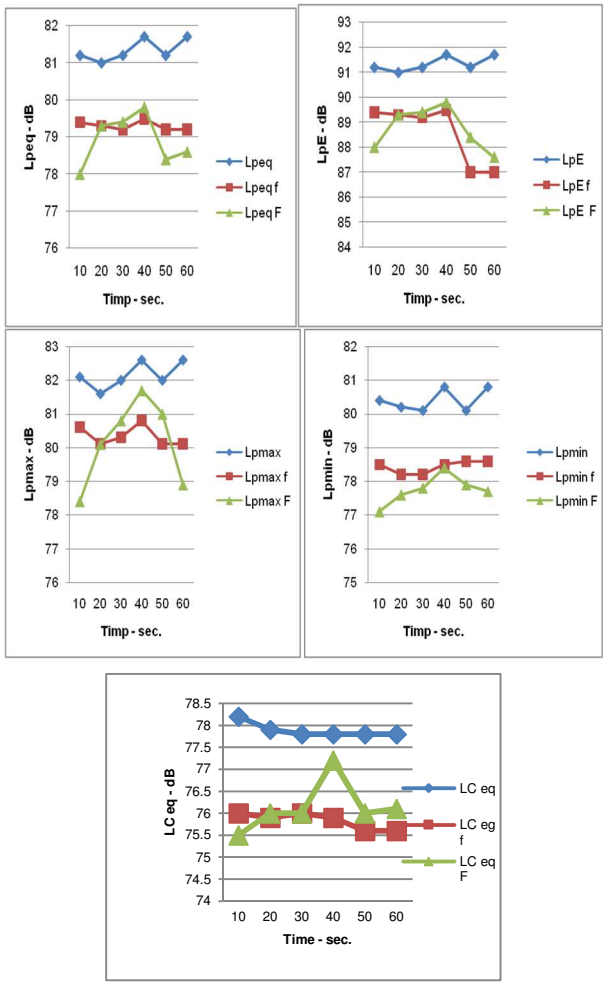


Fig. 13. Arrangement of Ficus benjamina + Ficus benjamina variegata

The Figure 13 demonstrated that the sound pollution diminishes with 3 dB (A) until 4.5 dB(A) using as the absorbent plants the combination formed Ficus benjamina + Ficus benjamina variegata in front of the arrangement. Measurements in front of the arrangement had a decrease in noise better than behind it.

3.2.5. Spatiphyllum wallisii

The assembly of them two sort of is Spatiphyllum wallisii in the figure 7, and there are two measurements for this arrangement, first in front of this (table 10 – red, noted s), second in back of this (table 11 – green, noted S). The five measurements will be represented in the graphs that follow the tables (fig. 14).

Table 10.

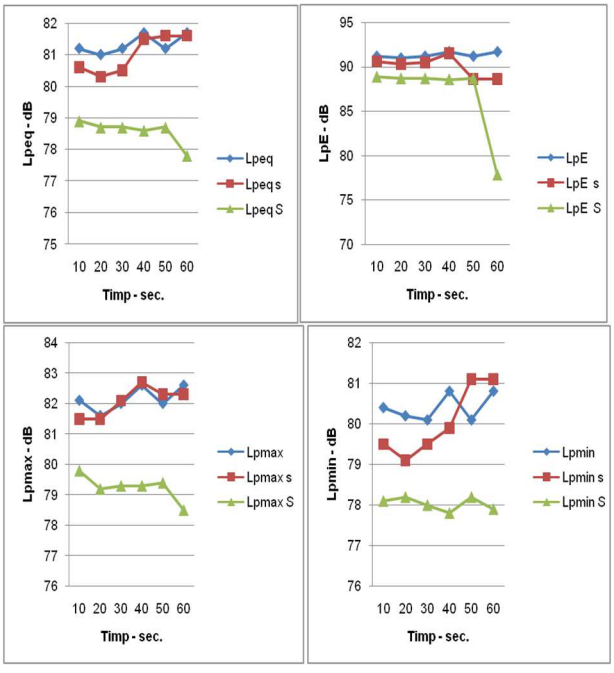
In front of Spatiphyllum wallisii – noted s

No.s	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	80.6	90.6	81.5	79.5	76.8
2.	80.3	90.3	81.5	79.1	76.8
3.	80.5	90.5	82.1	79.5	76.9
4.	81.5	91.5	82.7	79.9	77.1
5.	81.6	88.6	82.3	81.1	77.3
6.	81.6	88.6	82.3	81.1	77.3

Table 11.

In back of Spatiphyllum wallisii – noted S

No.S	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78.9	88.9	79.8	78.1	76.5
2.	78.7	88.7	79.2	78.2	76.5
3.	78.7	88.7	79.3	78	76.5
4.	78.6	88.6	79.3	77.8	76.1
5.	78.7	88.7	79.4	78.2	76.2
6.	77.8	77.8	78.5	77.9	75.8



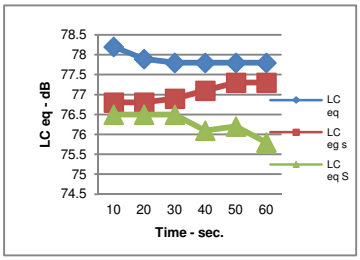


Fig. 14. Arrangement of Spatiphyllum wallisii

The Figure 14 demonstrated that the sound pollution diminishes with 2.3 dB (A) until 3.5 dB(A) using as the absorbent plants the combination formed Spatiphyllum wallisii in to two sort of them, if the measurement made behind the arrangement. The measurement in front, or without plants has the images almost superimposed.

3.2.6. Heptapleurum arboricola – Schefflera

There are two measurements for this arrangement, first in front of this (table 12 – red, noted h), second in back of this (table 13 – green, noted H).

Table 12.

In front of arrangement – noted h

No.h	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	79.6	89.6	82.1	78.8	76.1
2.	79.7	89.7	81.1	78.7	75.9
3.	79.7	89.7	80.6	78.4	76
4.	79.6	89.6	80.4	78.7	76.2
5.	79.4	89.4	80.4	78.7	75.9
6.	79.7	89.7	80.6	78.5	76.4

Table 13.

Behind the arrangement – noted H

No.H	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	78.2	88.2	78.9	77.6	75.7
2.	79.3	89.3	84.1	77.3	76.3
3.	78.4	88.4	79.3	77.5	75.9
4.	78.1	88.1	78.6	77.2	75.6
5.	78.3	88.3	79.4	77.6	75.8
6.	78.1	82.9	78.5	77.4	76

For a good understanding, the five measurements of the Heptapleurum arboricola – Schefflera arrangement are printed in graphical representations (fig. 15). It follow the tables with the registered measurements.

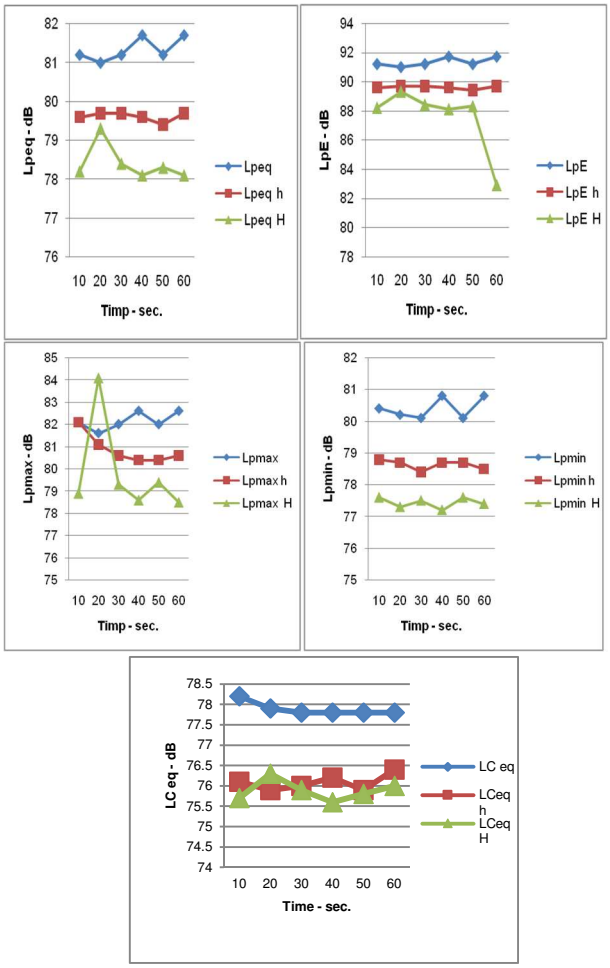


Fig. 15. Arrangement of Heptapleurum arboricola – Schefflera

This arrangement diminishes with 2dB(A) in front about the situation without plants, and diminishes with about 4dB(A) if the measurement was made in back about the plants. This has a good meaning for the sound absorption.

3.2.7. Philodendron scadens

There are two measurements for this arrangement, first in front of this (table 14 – red, noted p), second in back of this (table 15 – green, noted P).

Table 14.

In front of Philodendron scadens – noted p

No.p	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	80	90	80.8	78.9	76.5
2.	79.7	89.7	80.7	78.9	76.3
3.	79.7	88.2	80.8	78.7	76.1
4.	80	90	80.8	78.9	76.5
5.	79.7	89.7	80.7	78.9	76.3
6.	79.7	88.2	80.8	78.7	76.1

Table 15.
In back of Philodendron scadens – noted P

No.	Lpeq	LpE	Lpmax	Lpmin	LCeq
1.	79	89	79.7	77.8	76.5
2.	78.9	88.9	79.4	78.4	76.5
3.	79	89	79.6	78.1	76.7
4.	79.6	89.6	80.9	78.5	77.1
5.	79.3	89.3	80.2	78.3	77
6.	79.3	89.3	80.3	78.2	76.7

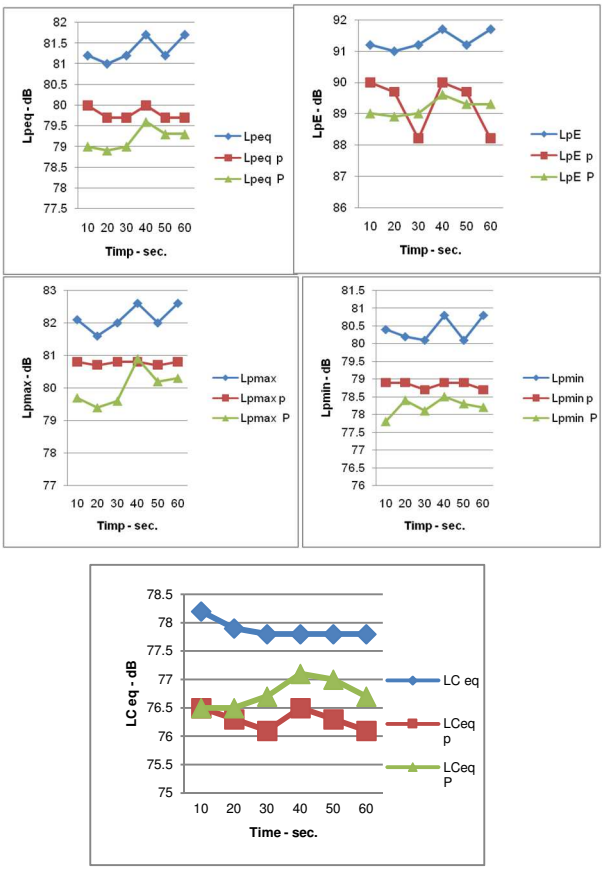


Fig. 16. Arrangement of Philodendron scadens

For a good understanding, the five measurements of the Philodendron scadens arrangement are printed in graphical representations (fig. 16).

Figure 16 shows that sometimes in front of arrangement is higher sound good attenuation than the back. As a result of Philodendron scadens here should be put after the human operator, not in front of it.

4. CONCLUSIONS REGARDING THE USE OF THE PLANT AS SOUND POLLUTION ATTENUATOR

In the third chapter of this work are presented in detail measurements made on sound pollution due to a ventilation system that operates outside of a fabric, what print material for the food industry.

To mitigate noise pollution of main source were used six varieties of plants, placed on a support website at 1 m towards the source.

Measurements were performed acoustic power with sound lever meter NL – 32 a device with the proper registration accuracy, in three distinct positions, without plants, in front of plant barrier and behind it.

It is considered significant the variable Lpeq, which is synthesized in summary table (table 16). In this table, select data and are made four graphical representations.

Table 16.
Centralization of measurement for Lpeq

Time [s]	Lpeq	LpeqBT	LpeqT	LpeqB	LpeqF	LpeqS	LpeqH	LpeqP
0:00:10	81.2	78.3	77.8	78.8	78	78.9	78.2	79
0:00:20	81	78.6	78.2	78.9	79.3	78.7	79.3	78.9
0:00:30	81.2	78.5	78.6	78.7	79.4	78.7	78.4	79
0:00:40	81.7	78	78.3	78.3	79.8	78.6	78.1	79.6
0:00:50	81.2	78.3	78.5	78.4	78.4	78.7	78.3	79.3
0:00:60	81.7	78.7	78.1	78.9	78.6	77.8	78.1	79.3
Lpeq average [dB]	81.3	78.4	78.3	78.7	78.9	78.6	78.4	79.2
Average Attenuation [dB]	0	2.9	3.1	2.7	2.4	2.8	2.9	2.1
Lpeq average [%]	100%	96.4%	96.2%	96.7%	97.0%	96.6%	96.4%	97.4%
Average Attenuation [%]	0%	3.6%	3.8%	3.3%	3.0%	3.4%	3.6%	2.6%

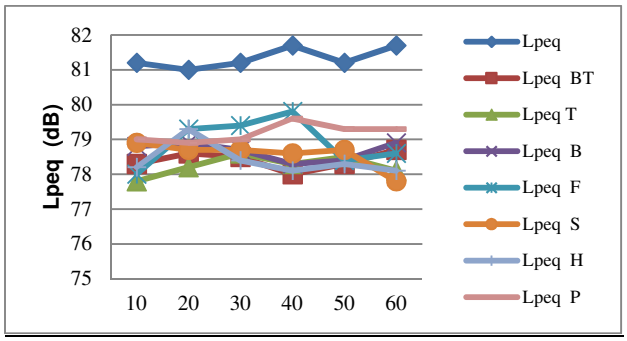


Fig. 17. Lpeq Variation dependent on plant species

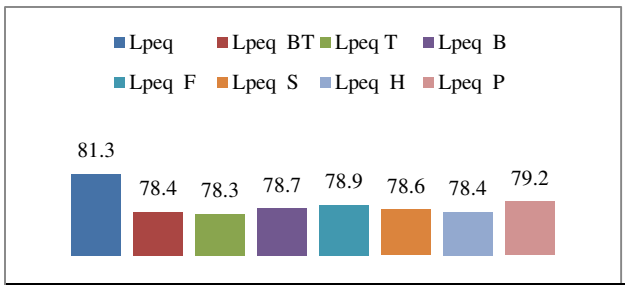


Fig. 18. Average Lpeq [dB] dependent on plant species

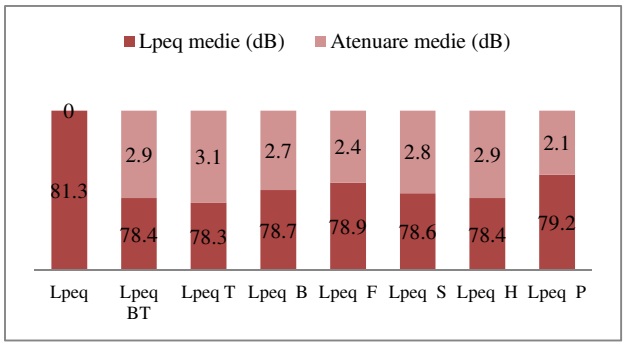


Fig. 19. Average Lpeq [dB]/Average Attenuation [dB] dependent on plant species

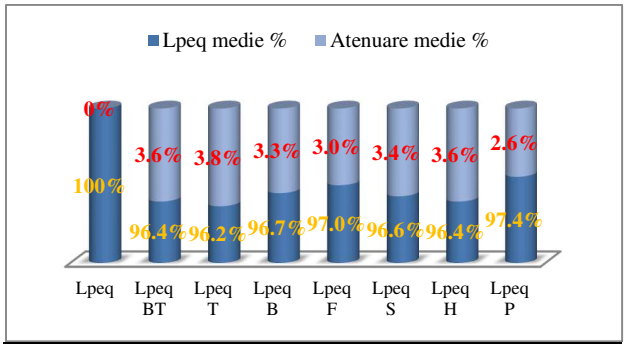


Fig. 20. Average Lpeq [%]/Average Attenuation [%] dependent on plant species

In Figure 17 are found a reduction of equivalent sound pressure in the case of Thujei and Heptapleurum; a satisfactory outcome if one reduced Spatiphyllum case Ficusului and the Philodendronului.

In Figure 18 are found as first is the Thuja, followed closely at par of Buxus+ Thuja, Heptapleurum, Spatiphyllum, Buxus, Ficus and Philodendron on last place.

From Figure 19 it may be said that attenuation varies in function of the studied species between 2.1 and 3.1 dB.

If is calculated this percentage of attenuation, plants fail to reduce of industrial noise pollution between 2.6% and 3.8%, as shown figure 20.

From the above, it can be said that, a relatively small number of plants may produce a good noise attenuation resulting from industrial activity.

It has been proven that there is a significant mitigation of noise pollution due to prezenței of the studied plants. Even if the measurements were done outdoors were used both as outdoor plants and indoor, in desire to cover a range of plants as possible.

For mentioning, the plants were so placed that to 1.5 m (for the human opperator ear), where measurements were made to either the crown of the plant, or height air part to have the most rich in plant leaves.

Acoustic absorption depends on the size of the plant form, of its rigidity and the size of the leaves, as well as and their age.

The final conclusion of this study is that both plants of interior and exterior ones, reduced noise pollution.

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Studiu experimental privind utilizarea regnului vegetal ca atenuator al poluării sonore produs industrial

Rezumat: *Lucrarea prezintă un studiu experimental asupra utilizării regnului vegetal ca atenuator al poluării sonore. Se studiază un sistem de şase plante ornamentale, plantate in ghivece individuale, dispuse pe un raft metalic, în faţa unei surse de poluare sonoră, o staţie de ventilare, ce deserveşte două hale industriale ale unei fabrici de imprimare materiale pentru industria alimentară. Această lucrare este o parte a unui studiu în ceea ce priveşte evaluarea poluării sonore în activitatea industrială.*

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