Road traffic noise reduction by vegetation in the ring road of a big city

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Abstract
This study was designed to investigate the traffic noise attenuation by vegetation along the ring road of Thessaloniki. Measurements were taken of road traffic noise at two areas, one through a belt of trees and the other above grass-covered ground. 245 measurements were taken in each area during a period of 2 months and expressed as differences in L_{Aeq} (equivalent constant A- weighted sound pressure levels). Also there were measurements for the number of vehicles per minute, the type of vehicles and analytic description of vegetation at both areas. The results showed a significant noise reduction through the belt of trees rather than above grass-covered ground. According to the results of this research the largest reduction, 6 dB, was seen in the *Pinus brutia* belt, 60 m away from the road. This reduction of noise pollution is judged satisfactory because there are belts of trees on both sides of the ring road.
Keywords: noise pollution; belts of trees; noise reduction; vegetation.

1. INTRODUCTION

Noise is not simply a local problem, but global issue that should concern us all [1,2]. In the European Union over 40% of the population is exposed to noise of motorways to a level, which exceeds 55 dBA during the day and the 20% of the populations to levels that exceed 65 dBA [3]. Sound pollution continues to expand with an increasing number of complaints from the residents. Most people are usually exposed to more than one source of noise of which motorway noise is the main source [4]. In order to study noise, we must separate the different types of noise, the way that we measure them, their origin and their effects on people. In 1993, the World Health Organization (WHO) [5] recognized the following effects on the health of the population that can emanate from noise: sleep patterns, cardio respiratory and psycho physiological systems, and hearing. It also affects us negatively on intervention in communication, productivity and social behavior [6,7,5].

The aim of this research is to locate and to evaluate the effect of vegetation on the reduction of circulatory noise that emanates from highways. In particular:

1. Is circulatory noise decreased by vegetation and if yes by how much?
2. Which are the characteristics of vegetation (type, structure) that affect the reduction of circulatory noise?
3. What is the necessary treatment to be applied to vegetation for a great reduction in circulatory noise?

2. MATERIALS AND METHODS

Measurements were taken at two different areas near residential zones each one 500 m^2. The first area is grassland while the second is forest of *Pinus brutia.* Both areas were 4 metres higher than the road and level (0-5%). The terrain was selected so that the two areas would be roughly similar.

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In this way the sound distribution was not differently influenced.

Noise intensity was measured using the Sound level Meter 407735 Extech Instrument, which has 2 measurement standards A and C, and we used only the A-standard [8]. The instrument was placed in height of 1,8 m above the surface as it is proposed by FHWA [9] and was turned to face the road. In both areas a straight line of measurement was made at right angles from the road to point 60 metres away. Measurements were made in 7 places every 10 metres along this line, starting at the edge of the road at point 0 [10,11]. In every place seven measurements were taken, each of 5 minutes duration. This was done 35 times in both areas over a period of 2 months from 9.00 a.m. to 2 p.m. In total 245 measurements were taken in each plot.

In the forest area it was measured the main silvicultural parameters of the trees: height in m, diameter in cm and the crown length in m. The height and the crown length of trees were measured with the altitude Haga.

All the measurements were computer registered with the use of statistical package of SPSS version 10.0 for windows. To check the effect of the vegetation factor on dependent variable highway noise the t-test was used [12] and the test Levene was used to check the homogeneity of fluctuation [13]. Diagrams of dissemination and the box-and-whisker plot on both areas studied were made.

3. RESULTS AND DISCUSSION

The mean circulatory pressure is 120.28(±7.67) vehicles/min, the number of big vehicles is 30.00(±1.95) vehicles/min and the proportion of heavy vehicles 24.85(±0.50) (all the measurement are represented as mean±s.e.). From 9 a.m. to 2 p.m. the Thessaloniki ring road is particularly busy and there is a high proportion of lorries. These heavy vehicles raise the level of noise as they pass (table 1).

Table 1. The intensity of noise due to heavy vehicles.

Surface	Distance from street	Noise intensity (dB)	Intensity of noise with the passage of big vehicles (dB)	Type of vehicles
	40	65.2	67.3	lorry
	0	76.1	81.3	lorry
	30	65.6	68.1	lorry
	40	65.3	74.7	lorry
	10	70.8	75.1	lorry
	20	67.9	71.3	lorry
	40	64.8	68.3	motorcycle
grassland	0	81.0	86.1	lorry
	50	62.7	70.0	lorry
	60	61.7	65.6	lorry
	0	77.9	92.9	ambulance*
	30	65.4	72.9	lorry
	10	72.7	77.7	lorry
	0	79.2	85.4	motorcycle
	0	78.5	85.2	lorry
	20	66.0	79.9	ambulance*
	0	80.2	90.1	lorry
forest	0	80.4	83.2	lorry
	0	78.8	83.2	lorry
	10	69.7	75.3	lorry
	10	69.5	77.8	lorry

* The ambulance had in operation the sirens.

3.1 Description of vegetation

The grassland is degraded with plants of families *Compositae*, *Solanaceae* and various other broadleaved plants. Horses occasionally graze there. The vegetation of the forest is reforestation of *Pinus brutia* with planted at 3x3m intervals. There are no bushes under the crown of the trees, only a few plants. The main silvicultural parameters of the green belt were: tree height 8.68(±0.22)m, tree diameter 18.94(±0.78)cm, the crown started above ground at 1.04(±0.17)m and finally the total crown length was 6.72(±0.19)m (all measurement are represented as mean±s.e.).

3.2 Reduction of intensity of noise

It was found that at 60m from the road the intensity of noise in the forest was on average 6 dB less than in the grassland. A presentation of the results of statistical analysis in the two surfaces is given in the table 2 and the figure1 with box-and-whisker plots.

Table 2. Results of statistical analysis the values that are not followed by the same letter differ significantly (a=0.05, t-test).

surface	variable	Distance from the road	mean	median	standard deviation	min	max	range	Coefficient of variation
grassland	dB	0	78.36[a]	78.40	0.86	76.1	81.0	4.9	1.09
		10	71.80[a]	72.35	1.27	69.3	73.3	4.0	1.76
		20	68.07[a]	68.00	0.49	67.3	68.8	1.5	0.71
		30	65.50[a]	65.50	0.28	64.7	66.0	1.3	0.42
		40	63.96[a]	63.75	0.64	63.0	65.3	2.3	1.00
		50	61.94[a]	61.80	0.50	61.1	63.2	2.1	0.80
		60	60.50[a]	60.45	0.68	59.3	61.9	2.6	1.12
forest	dB	0	78.70[a]	78.55	0.69	77.6	80.4	2.8	0.87
		10	69.56[a]	69.60	0.20	69.0	69.9	0.9	0.28
		20	65.43[a]	65.40	0.29	65.0	66.0	1.0	0.44
		30	62.51[a]	62.50	0.26	62.0	61.1	1.1	0.41
		40	59.50[a]	59.50	0.27	59.0	59.9	0.9	0.45
		50	56.51[a]	56.60	0.26	56.0	56.9	0.9	0.46
		60	54.72[b]	54.60	0.54	54.2	57.7	3.5	0.98

From the table 2, the following was observed: At the distance 0m from the road, the factors of variation which are the unique characteristics of relative variation are big and in both cases. In the forest its value is 0.87, smaller than the value of 1.09 in the grassland.
At a distance of 10m from the road the factors of variation in the grassland are prevailing in the forest than in the grassland.

At the distance of 60m from the road the factors of variation of intensity of noise and in the two surfaces are roughly equal. This is due to the gap that exists in the forest from 50-60m, therefore there is no positive effect of the crown of trees and the sound behaves as in a region that does not have high vegetation.

The box-and-whisker plot shows a graphic presentation of information on the distribution of data that are examined. The values of inferior and superior percentile (25^{th} and 75^{th} percentile) determine the beginning and the end of the box-and-whisker, which contains the intermediate 50% of prices of data. The horizontal line that cuts the box-and-whisker depicts the median.

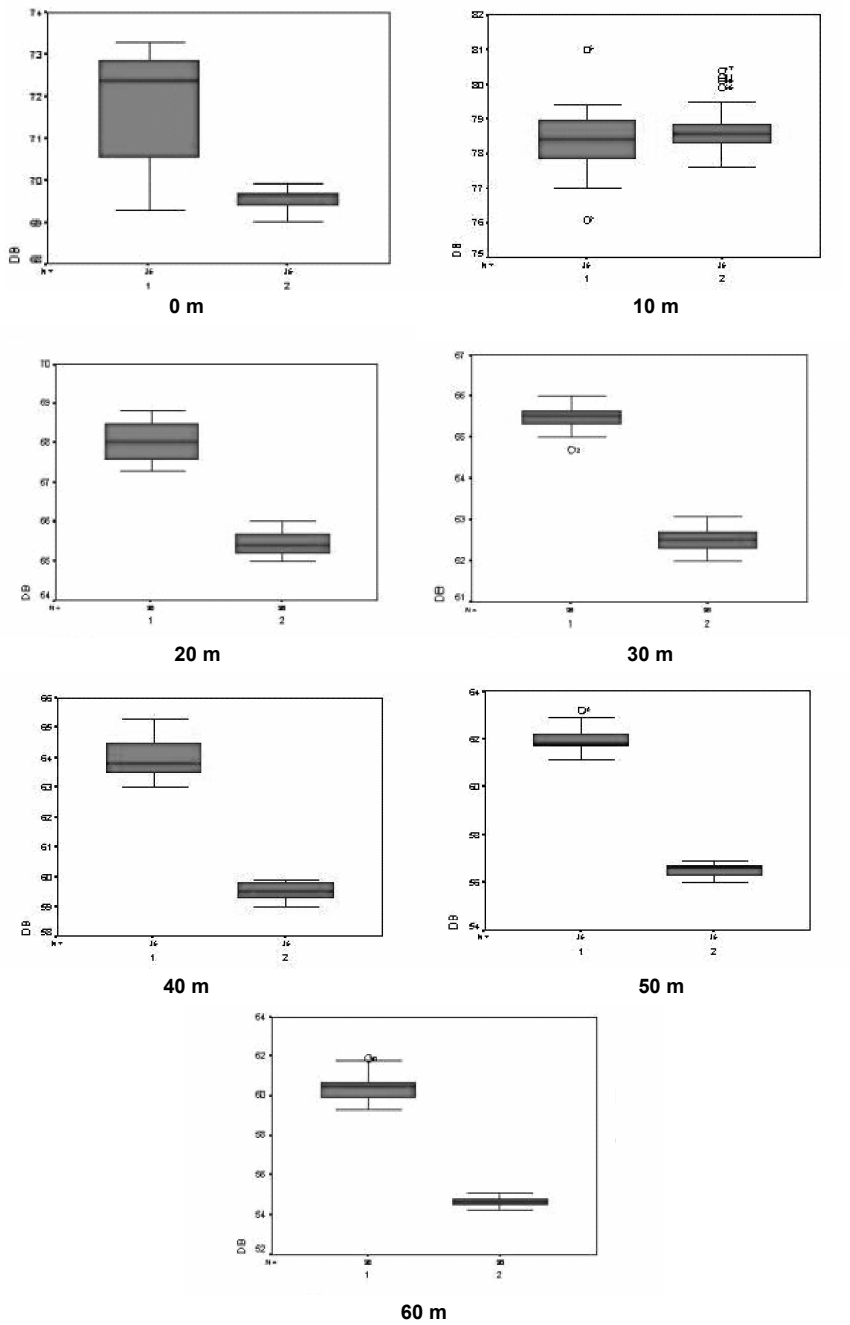

Figure 2. Box-and-whisker plots of intensity of noise at the grassland (1) and at the forest (2) at distance 0,10,20,30,40,50,60m from the road.

4. CONCLUSIONS

The levels of noise pollution in the ring road of Thessaloniki are above the limits stated by Greek legislation 29087/2295 (67 dB). This is due to the high speed of vehicles, to the amount of traffic and to increased passage of heavy vehicles.

By the analysis of the results, it can be understood that the vegetation functions as a plant noise barrier decreasing the intensity of the noise.
- The vegetation can decrease satisfactorily the intensity of traffic noise in streets with rapid circulation. In the area of green with reforestations of *Pinus brutia* a bigger reduction was observed at 6 dB 60 m than in the grassland surface.
- The reduction of noise pollution is judged satisfactory here because areas of green exist in most places on both sides of the road
- In the existing areas of green that are found along the ring road the following characteristics of vegetation were recorded. The high vegetation constitutes only of trees of *Pinus brutia.*

5. PROPOSALS

- Evergreen bushes (2-3 metres height) should be planted in rows close to the road edge. *Ligustrum vulgare*, *Pitosporum tobira*, *Pyracantha coccinea* and *Phillyrea latifolia* are suggested [14]. Then a tree barrier should be planted. These trees must be of at least 15 metres height when mature. This combined green zone must be at least 20 metres in depth.
- As well as coniferous trees, deciduous trees may also be planted such as *Cercis siliquastrum*, *Celtis australis*, *Fraxinus ornus*, *Ostrya carpinifolia*, *Carpinus orientalis* and *Acer campestre*. Also it should be used the suitable tree species according to the prevailing circumstances in the urban and periurban environment [15,16,17,18,19]. It is suggested avoiding the use of *Olea europea* as its blossom is an allergenic [20]. It can only be used if pruned regularly so that it does not blossom, but also dense hedges are formed.

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