INVESTIGATION OF THE EFFECTS OF LEAVES, BRANCHES AND CANOPIES OF TREES ON NOISE POLLUTION REDUCTION

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ABSTRACT

In order to determine the effects of tree branches, leaves and their canopies on noise pollution, different types of trees from the Chitgar forest park in Tehran were investigated and compared in the seasons of spring and fall. Noise values were taken with noise meter equipment at four points of measurement: (a) an open area as the control treatment (without trees), urban forests of pure stands of (b) *Pinus eldarica*, *Robinia pseudoacasia*, and (c) a mixed stand at 7 distances (10, 20, 30, 40, 50, 75 and 100 meters from the source of the noise which was located behind the tree stands). The experiment was repeated five times in the above mentioned seasons. The noise pollution of the region was also taken into account. The results indicated that in the studied area, the average noise level was more than the Iranian national noise standard. The largest noise reduction occurred in the mixed stand, which was about 19.07 dB(A) and the lowest amount of reduction was seen in the pure stand of *Robinia pseudoacasia* which was about 14.7 dB(A). The most significant noise reduction took place 75 meters away from the source of the noise. The differences between noise pollution abatement of the pure stand of *Robinia pseudoacasia* and the mixed stand in spring and fall were 5.01 and 6.05 dB(A), respectively. The results of this study suggest that in order to solve the issue of noise pollution of industries and road traffic, especially in big cities like Tehran, noise barriers need to be specified in city construction in specific zones that are covered with trees and vegetation with appropriate width.

Key words: Noise pollution, mixed stand, fall season, Chitgar forest park, pure stand.

1. INTRODUCTION

With increase of pollution and means of transportation and the development of industries, the range of noise pollution and unwanted noises have increased greatly [1,2]. As a result, in metropolises, noise pollution (after air and water pollution) is considered to be the third most serious kind of pollution by the World Health Organization [3].
Robert in the 19th century has stated that the most important problem of human beings in the next century is not infectious diseases but noise pollution [4].

Investigations have revealed that an individual can tolerate a certain amount of noise pollution in his or her lifetime [5]. But noise pollution has many detrimental effects on human beings, both mentally and physically [6]. Therefore, managing and reducing noise pollution should be strictly considered and the most efficient methods of noise reduction should be selected from existing methods [7].

The biggest source of noise in cities is vehicles and road traffic, forcing residents to escape the clamorous roadsides and take refuge in quieter spots [8]. Some studies were conducted in urban regions with high road traffic (60-80(Decibel dB(A)) and the results indicated that using green areas is recommended to promote better health and eliminate disturbing and stressful noises.

Creating greener areas and providing easy access to them in order to reduce the environmental stress and noise pollution that arises from traffic deems necessary business [9]. Numerous studies have been conducted to find way to reduce the negative effects of noise pollution [10,11]. Yang and Gun [12] believe it is practicable to use noise barriers, particularly during rush hours to either break or absorb the noise waves and reduce transmission of noise behind the barriers. Depending on the conditions, these barriers could be physical or biological or a combination of both. Hills, rising slopes, hedges and walls are appropriate noise barriers [13].

The effects of planted trees in urban forests on noise pollution reduction have been demonstrated in different studies [14,15]. Furthermore, various studies revealed that designing the highways with dense plant

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coverage not only eliminates noise pollution a rising from roads traffic but also beautifies the area [16,17]. Besides, the stress that is caused by noise pollution [18-20] could be reduced through creating forests near residential areas [21]. In addition, the evaluation of the features of plants which are supposed to be utilized in an urban green belt could be very useful [22].

The aim of this study was to investigate the effect of different tree plantations on noise pollution reduction in various widths and to compare their influence in different seasons (when the trees have leaves and when they have shed) in the Chitgar Forest Park of Tehran.

2. MATERIALS AND METHODS

2.1. Study area

The study area is located west of Tehran in Chitgar Forest Park with an area about 950 hectares between 51° 15´ and 51° 10´ east and 35° 42´ and 35° 45´ north.

Figure 1 shows the location of the area studied. This park was established in 1968 with some special aims such as air pollution reduction, making a green belt around Tehran, cleaning the air, making a recreational center, and preventing the inappropriate development of the city. The trees of the park can be divided into three major types including pure hardwood stands, pure softwood stands and mixed stands. Their density is about 800 trees per hectare. About 23% of the total area of the park is covered with *Robinia pseudoacasia* and 45% is occupied by *Pinus eldarica*.

The tree plantation lines are 1.8-2 m away from each other and the distances between trees in every line is 1.6-1.8 m. These plantations are about 45 years old. The studied area is considered as an arid Mediterranean climatic region with 1300 m elevation above sea level and a mean annual precipitation of of 232 mm.

2.2. Methods

To investigate the effect of trees on noise pollution reduction, noise values were taken at four measurement points; an open area without trees with the same topography as the other stands as the control treatment [23], urban forests of pure stands of *Pinus eldarica* (Fig. 2) and *Robinia pseudoacasia* (Fig. 3) and a mixed stand (Fig. 4), at seven various distances (10, 20, 30, 40, 50, 75 and 100 m) from the noise source behind tree stands. There were five repetitions in transects within stands and with ten meters distance from each other.

The noise level was measured at the mentioned distances with noise meter Model 9019 DELTAOHM HD. The noise meter could be calibrated with calibrator 9101HD on two levels of 94 dB (decibel) or 114 dB (optionally, in this study it was calibrated on the level 94 dB) and a frequency of 1000Hz. The heights of the noise meter and source were the same [24] about 1.5 meters above ground [25,26].

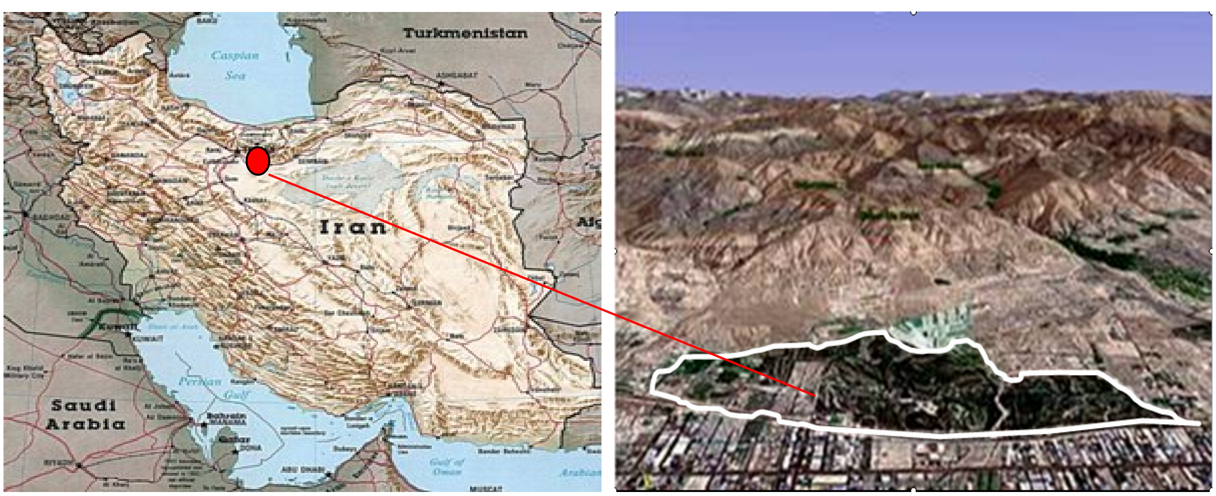

Figure 1 study area location

Figure 2 The pure stand of *Pinus eldarica* in the study area

Figure 3 The pure stand of *Robinia pseudoacasia* in the study area

Figure 4 The mixed stand in the study area

There was no elevation difference between the point of the source and the measurement points at different distances behind the tree stands due to the flat landform of the study area [23]. For this study, an amplifier was used as a noise source to produce a noise value of 101.5 dB(A) and a frequency of 1000 Hz. This noise value was measured at distance of 30 cm from the noise source. As the noise source was artificial and under control, at every measurement point five minutes was sufficient to record the noise level. The first measurement was carried out in the open area and was taken as the baseline data for each area [23].

At any point the noise level was first measured beside the noise source and then at seven different distances from the noise source at each transect. Noise values were measured in summer, when poplar trees had leaves and were repeated in the autumn after the trees had shed their leaves in similar conditions. At each measurement point the field noise level was noted as well. Generally, there were no extra sources of noise that could affect the measurements. In case of any disturbing or other accidental noises, the measurement was repeated in more favorable conditions.

To determine the noise levels of the region, the noise of traffic, building construction, industries, people, etc… were measured beside the road; for 30 minutes [27] and five replications. In this study the (Leq) parameter according to dB(A) unit was used to measure the amount of noise pollution. In this way the noise level would be determined in a manner that the equivalent acoustic energy during the measuring time, for example 5 minutes, is equal to the recorded energy of noises with different fluctuations in 5 minutes [28].

At every stand the DBH (diameter at breast height), height and canopy volume of trees were measured in three 10 m^2 plots using a selective statistical method. To calculate the canopy volume, two diameters of canopy were measured and then according to the shape of the canopies their volumes were calculated using appropriate formulas.

The SPSS (statistical package for social sciences) was used to analyze the data. The normality of the measured noise levels was examined with the Kolmogrov-Smirnow test and the homogeneity of variances was investigated with the Levene test. In addition to the normal distribution and homogeneity variances of the data, the Tukey HSD test was used to investigate and compare the noise pollution reduction of the three stands and the open area. The GLM (General Linear Model) test was also applied to examine the interactive effects of various distances and stands. The noise levels taken at the roadside were compared with the Iranian national standard noise levels using a one-sample-t-Test. Excel software was used to draw the diagrams.

3. RESULTS

The background noise of the study was about 40-41 dB. It was measured when there was no noise pollution produced by the amplifier at all stands and in the control area. Since its difference with the selected noise level of this stud y(101.5 dB (A)) was more than 9dB, the intensity level of field noise was ignored [29].

The studied area is considered to be a residental-industrial region and its noise level is about 101 dB(A), which is much higher than the national noise standards of Iran (Table 1).

Table 1 Iranian national noise standards

10AM-7AM Leq(30') dB(A)	7AM-10PM Leq(30') dB(A)	The type of regions
30	50	Residential
50	60	Residential-Commercial
55	65	Commercial
60	70	Residential-Industrial
65	75	Industrial

The results of an open area with no trees or other hindrance showed that sound reduction occurs via normal attenuation and excess attenuation [30,31]. Normal attenuation is due to the spherical divergence [32] and friction between the atmospheric molecules when sound progresses [31]. Such a phenomenon has been termed the distance effect. Noise attenuation increases with the increase of distance. Furthermore, reflection, refraction, scattering and absorption effects, due to any obstruction between a noise source and a receiver, result in excess attenuation [30,31]. The barrier effect is an example of the latter and is measured via relative attenuation. Table 2 shows the attenution of the measured noise level in the open area (normal attenuation) and the double attenution caused by distance and different tree types 100 meters away from the noise source. Table 3 presents the amount of noise pollution abatment in various types of trees dispensing with the effect of distances.

The results in these Tables demonstrate that although increasing the distance causes noise reduction, the rate of noise level reduction is not the same. By going 75 meters away from the noise source, the most increasing rate happens beyond this distance. As is clear in Figure 5, the rate of noise level reduct-ion decreases.

Comparison of the effect of different types of trees on noise attenuation in the summer presents a significant change ($P<0.05$) of noise pollution reduction caused by various distances in the tree stands. As evident in Figure 6, the mixed stand has the highest amount of noise attenuation in the summer when trees have leaves, which is 70.6 dB(A), and after that the highest amount of attenution belongs to pure pine stand with reduction in the quantity of 68.6 dB(A). The lowest amount of noise attenution occurred in pure locust tree stands, which was 66.4 dB(A). If the influence of attenution caused by distance is deducted, the noise attenutaion for these three types according to table 3 would be 19.0,16.9 and 14.7, respectively.

Table 2 The noise pollution attenuation caused by different speacies and distance of 100 meter away from the noise source

Noise Attenuation \ Type	Open area	Pinus eldarica	Robinia pseudoacasia		Mixed Stand	
			summer	fall	summer	fall
Attenuation dB(A)	51.7	68.6	66.4	61.3	70.6	64.6

Table 3 The average of noise pollution attenuation in different tree types 100 meters away from the noise source

Noise Attenuation \ Type	Pinus eldarica	Robinia pseudoacasia		Mixed Stand	
		summer	fall	summer	fall
Attenuation dB(A)	16.9	14.7	9.7	19.0	12.9

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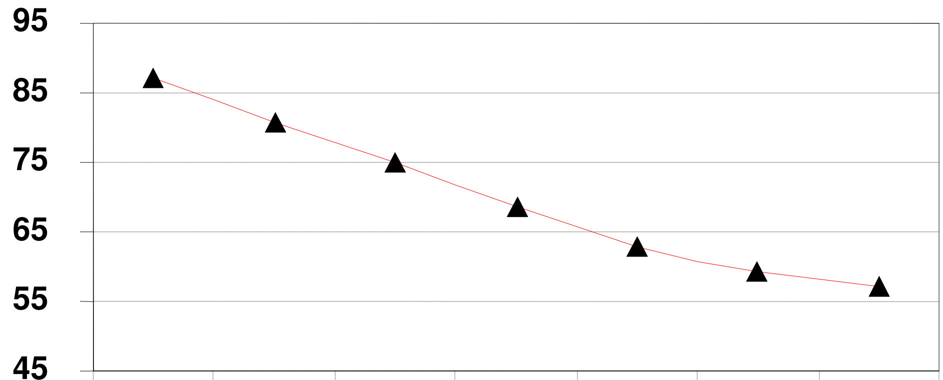
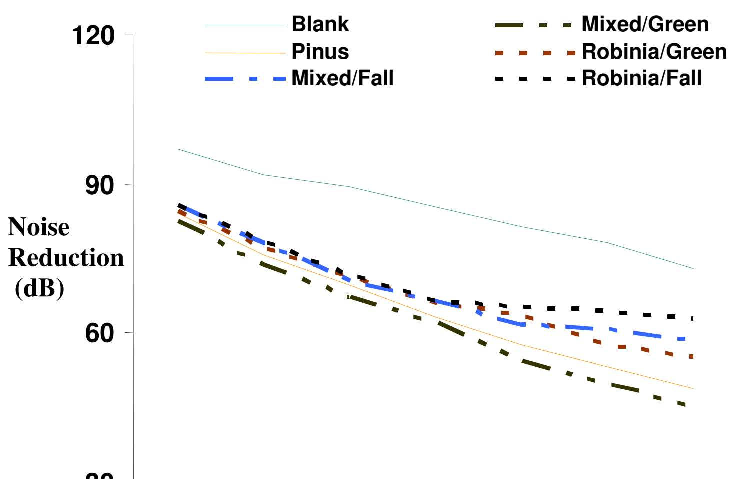


	10	20	30	40	50	75	100
Noise values	87.1	80.6	75.0	68.6	62.8	59.3	57.3

Distance (m)

Figure 5 The effect of distance and tree belts on noise attenuation



	10	20	30	40	50	75	100
Blank	97.1	91.8	89.5	85.3	81.3	78.3	72.9
Mixed/Green	82.5	73.7	67.3	62.3	54.6	50.2	45.4
Pinus	84.4	75.7	69.7	63.2	57.8	53.1	49.0
Robinia/Green	84.8	77.4	71.4	66.2	63.7	57.9	55.2
Mixed/Fall	85.8	78.2	70.5	66.5	61.8	60.9	58.6
Robinia/Fall	86	78.6	71.8	66.7	65.3	64.8	62.9

Distance (m)

Fugure 6 Comparison of the effect of distances from noise source on noise attenution in different tree types

Table 4 Tree measured parameters of three different stands

Tree stands	Canopy Volume (m^3)/ ha	DBH (cm)	*Height (m)*
Pinus eldarica	2111	20.99	*11.48*
Robinia pseudoacasia	1655	18.17	*7.9*
Pinus eldarica	*2378*	*15.87*	*8.95*

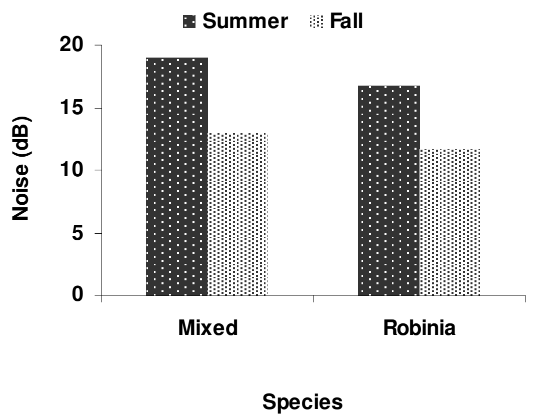


Figure 7 Noise attenuation in summer and fall in a mixed stand and a pure locust trees stand 100 meters away from the noise source

Furthermore, in comparison to the effect of tree foliage on noise reduction in summer (when trees are coverd with leaves) and fall (when they had shed their leaves) significant changes (P<0.05) were noticed(Figure 7). According to Table 3 these changes are about 5.01 dB for pure locust trees and about 6.05dB for mixed stand.

The measured tree parameters (canopy volume, DBH and height) of the three examined stands are presented in Table 4. As it is obvious, the highest canopy volume is related to the mixed stands, about 2378 m^3 per hectare; and the lowest one was for a pure *locust tree stand*, about 1655 m^3 per hectare. The highest amount of noise pollution was also observed in the mixed stand, pure pine trees and pure locust trees, respectively. Pure *Pine stand* has the highest DBH of 21.0 cm and the mixed stand has the smallest DBH of 15.9 cm. Considering height, the trees can be arranged from the highest to the lowest according to this order: *pure pine trees*, mixed *stand* and pure *locust trees* with height values of 11.5, 8.1 and 7.9 m, respectively.

4. DISCUSSION

The present study has refocused on the importance and necessity of the use of trees against noise pollution. It is clear that with increase of the distance from the source of noise and tree belt widths the noise pollution decreases. Generally, by going far from the source, noise reduction occurs via normal attenuation and with increasing the distance the noise attenuation increases [30,31]. In addition, by increasing the distance the scattered frequency areas become more extensive so naturally the noise will decrease.

Various widths of tree belts and the amount of their effect on noise attenuation have been investigated in different studies. Among them [33] width claimed that forest stands and tree belts with at least 12 meters can be used efficiently as noise barriers in urban areas. In another research [34] examined the effect of plant coverage on noise pollution reduction using natural and artificial noise sources with a specific frequency and came to this conclusion that a belt of trees with a width of 30 meter planted on a roadside can increase the noise by about 6dB more than a grassland on roadside.

Williams and MC Creae [35] measured a noise attenuation of 4-8dB (A) behind a tree belt with 30 meter width. Ozer et al. [23] suggested the planting of tree belts of 100 meter width and considered planting techniques and suitable tree species from the viewpoint of beautification and ecological conditions.

The reason of the different effects of pure locust trees and mixed stands on noise pollution reduction in the green season (respectively 5.01 and 6.05 dB) can be explained with the roles of branches and leaves of trees as barriers to reflect, refract, scatter and absorb sound waves. These components will reduce noise in the green season when trees have more branches and leaves. This matter has been demonstrated in different studies of various researchers. For example, the effects of leaf size and branch forms of deciduous trees on scattering and reduction of acoustic energy were verified by Aylor [36] and Cook and Hoverbeke

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[37]. They concluded that less visibility, higher intensity and more branches and leaves have better influences on noise pollution reduction. Also, Price [38] computed the amount of noise reduction in deciduous stands in winter and spring and clearly observed the effect of leaves on noise reduction. She stated that the best stands as noise barriers are mixed stands of various tree species with more leaves. Furthermore, Aparicio and colleagues [39] stated that plant leaves absorb acoustic energy by transferring the kinetic energy of the vibrating air to the vibration pattern of the leaves. Therefore, vibration energy is withdrawn from the acoustic field and part of this energy is lost by conversion to heat since leaf friction occurs in a vibrating plant. Finally, a study Ozer and colleagues in [23] concluded that pine trees perform more efficiently than fir trees in noise attenuation: this difference was measured at about 6.3 dB(A) at 25 meters from noise source. They stated that the reason is that the leaves of pine trees are denser than fir tree leaves. The difference between the present study and other studies is to choose the best species and optimum tree belt widths due to the age, size and different plantation patterns of trees. Our results indicate that the best case to have the highest effect on noise attenuation is to plant mixed stands of 75 meter width.

The noise attenuation results obtained at a distance of 100 m in Chitgar Forest Park are numerically larger than those mentioned in the literature cited. This is due to the smaller reference distance of 100 meter generally quoted in the other studies. In addition, the measurements of this study were made only under windless conditions during which sound waves would be expected to follow more or less straight paths from the sound source to the microphone. Under these conditions the sound path of interest is totally contained within the forest canopy so that sound attenuation by foliage would be expected to be maximal.

5. CONCLUSION

Almost all countries and among them Iran are witnessing the population growth. The increase of vehicles, developments in industries lead to noise pollution as a result. Tehran as a big and developing city has encountered this environmental issue like other metropolises. In this study it was concluded that urban green areas and particularly trees have a momentous role to reduce the noise pollution. Chitgar forest park can be considered as a border between the industrial and residential areas of the west of Tehran and prevents the residents from exposure to noise pollution. Considering the outputs of this study about the effect of various tree species, canopy volume and foliage on noise attenuation, it could be claimed that in order to have the optimum influence of forestations and green area plantations on noise attenuation, mixed stands must be planted in belts with suitable width.

In order to design the cities and green areas to create noise barriers (except botanical features of species), it is essential to consider the ecological conditions of the region from the viewpoint of providing an appropriate bed for species growth and species selection with high canopy volume and considerable foliage.

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