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FOREST'S SCREENING EFFECT ON DISTRIBUTION OF TRAFFIC NOISE

Summary

Noise is one of the most popular environmental pollution. Long-standing residence in noisy areas can cause discomfort, problems with sleeping, neurosis, etc. Because of moving sources and increasing the number of routs, communicative noise is drudging on the huge areas. The level of noise emitted depends on the number of vehicles, as well as their types, speed and technical condition and also the type of routs pavement. Propagation of acoustic waves in the roadside area is stipulated by sound's source energy as well as characteristics of the emitter. Forest ecotone zones and roadside afforestation constitute a certain ecological filter buffering contaminations generated by traffic. Trees and shrubs growing in the vicinity of routs are able to reflect as well as absorb noise. They can form natural acoustic screen.

The paper presents an assessment of the propagation of communicative noise on the forestry areas by analysis of variance. Researchers were carried out in the forest area, urban and park forests. Evaluation of noise propagation was conducted in January and July 2006. The measurements' intensity of noise was interpreted according to model three-factor linear model as well as two-factor linear model.

Measuring points were located in different distances away from the crown road (factor A). Researchers were carried out in winter and vegetation periods (factor C). The results obtained on forest areas were compared with those of non-forest control areas (factor B). For comparison purposes research was also carried out near the polycarbonate acoustic baffle.

On the basis of analysis of variance it can be noticed that all null hypothesis of main factors effects are rejected in favour of alternative hypothesis at significance level α=0.01. It means that each factor influences on the level of communicative noise. The carried out research showed that the most important factor which determines noise propagation is plant cover. The equivalent noise levels were similar in both research periods in the afforestations situated in Złotniki, the national road 11 and Poznań, the Umultowska street. It results from the fact that the dominant species in the analysed afforestations was Pinus sylvestris L. The most significant equivalent level value decrease occurred in the 50m wide belt of the pine stand. The equivalent noise levels were similar in both research periods in the afforestations situated in Złotniki, the national road 11 and Poznań, the Umultowska street. It results from the fact that the dominant species in the analysed afforestations was Pinus sylvestris L. The most significant equivalent level value decrease occurred in the 50m wide belt of the pine stand. The approx. 30m wide pine stand reduces noise propagation both in winter and summer to a degree comparable to the polycarbonated acoustic screen. The broad-leaved shrub-belt in the Sołacki Park decreased the equivalent noise level value (by approx. 5 dB) only in the vegetation season.

Key words: communicative noise, propagation, plant cover, analysis of variance

INTRODUCTION

The environment has been facing the negative impact of noise since the beginning of humanity, both throughout antiquity, the technical and industrial revolution, and up till today. Roman authorities as far back as 100 years B.C. issued a set of regulations prohibiting noise-producing enterprises be located in the areas inhabited by scientists. Forming the acoustic climate is presently a priority task in the field of the environment protection. Noise is the commonest environmental pollution. Feeling of discomfort, sleep disturbances and various types of neurosis are caused by a long-period presence of noise in the area of our stay. Animals subjected to noise show changed patterns of behaviour (anxiety states, dying off of embryos, premature births etc.) [Kędzierska i in.1997]. It has been also noticed that plants react to sounds by growth disturbances [Retallach D. L. 1973]. The most bothersome emitters of noise are industrial plants and transportation vehicles.

Owing to mobility of its sources and growing network of transportation routes traffic noise is bothersome in vast areas. The level of the emitted road noise depends first of all on the number of the operating vehicles, their type, their speed and technical condition, as well as the type of road surface. Propagation of acoustic waves in the road-side zones is conditioned by the energy of the sound source and the characteristics of the emitter. Meteorological conditions (wind speed and direction, temperature distribution and moisture) [Lebiedowska 2006] show a significant impact on the propagation of sound energy in the conditions of open space areas. The level of noise in the environment, brought about by traffic, is described by the value of the equivalent level of sound.

EXPERIMENTAL PROCEDURES

The aim of the carried out investigations was to evaluate the propagation of traffic noise in afforested areas applying the method of the analysis of variance. The investigations were carried out in forest area, town and park afforestations. Measurement points were situated at various distances from the road crown (factor A). There were two measurement periods, i.e., winter and vegetation period (factor C). The obtained results of the equivalent level of noise in afforested areas were compared with the results obtained in non-afforested control sites (factor B). For comparative purposes equivalent noise level investigations were also carried out in the neighbourhood of a polycarbonated acoustic screen.

The evaluation of the traffic noise propagation was conducted in January and July, 2006.

Investigation sites:

1. The Żurawiniec Nature Reserve situated in the neighbourhood of the Umultowska street in Poznań.
2. Pine stand neighbouring the town of Złotniki situated close to the national road 11 (exit road from Poznań towards the north).
3. Shrub-belt in the Sołacki Park protection zone neighbouring an important city artery - the Niestachowska street.
4. The area neighbouring the Witosa street, protected by a policarbonated acoustic screen.

General characteristics of the research objects

The reserve of Żurawiniec was created in 1959 to protect the transitional moor plants association. At present, the area covers 1.47 ha and is an integral part of a bigger forest complex belonging to the city of Poznań. The species composition of the over-wood is represented by *Pinus sylvestris* L. and *Betula verrucosa* Ehrh. and the shrubs are dominated by *Prunus serotina* Ehrh. The traffic on the Umultowska street, neighbouring the Reserve, reached 9698 conventional vehicles daily in 2006.

The tree stand in Złotniki was also dominated by *Pinus sylvestris* L. and occasionally *Quercus rober* L. occurring in the forest margin, as well as *Acer platonoides* L. Traffic density amounted to approx. 26, 000 vehicles daily.

The noise measurements for two objects (The Umultowska street and national road 11) were carried out within the frame of two research transects i.e. in the afforestation and for controlling purposes in the non-afforested neighbouring areas. Each of the transects had 7 marked research points 10, 20, 30, 40, 50, 100 and 200 m away from the road crown. 25 sound measurements were carried out in each of the points.

The description of the influence of the shrubs on the propagation of traffic noise was carried out in the Sołacki Park close to the Niestachowska street. The park was created in 1907-1913 and today belongs to the most beautiful natural objects of the city of Poznań. 2018 trees grow presently in the Park. A detailed dendrological inventory carried out in 2006 took into consideration the species, breast height, as well as height and health condition of every tree [Czerniak 2006]. The Park's microclimate is conditioned by the little river Bogdanka and two ponds with irregular bank lines. The measurement points were placed at the road edge and 20 m from the edge. A shrub-belt of 10 m width occurred in the protection zone 5m away from the street. *Symphoricarpos album* L. 2m high was the dominant species in the afforestation.

Additionally, measurements were conducted for comparative purposes of equivalent noise level close to the polycarbonated acoustic screen constructed in the Witosa street.

The Witosa street is a continuation of the Niestachowska street towards the northern city exit by the national road 11. The measurement points were located at the road edge directly in front of the screen, as well as 4 and 20m away from the road (approx. 19m behind the screen).

Traffic density in both streets in focus was over 70,000 vehicles daily in 2006 according to the measurements carried out by the Poznań City Roads Management Office.

All the roads where the measurement points were placed had bituminous surface in a good condition. Longitudinal slope of the formation line of the surface did not exceed 3%. The Umultowska street and national road 11 had two lanes, whereas Niestachowska and Witosa six.

The measurements were carried out at the height of 1.5m from 8.00a.m. till 14.00 p.m. in agreement with the regulations in force [According to Polish standards: Dz. U. nr 62, poz. 627; Dz. U. nr 18, poz. 164; Dz. U. nr 35, poz. 308; Dz. U. nr 178, poz. 1841; Dz. U. nr 8, poz. 81]. The measurements of the noise level were conducted by help of the sound level analyser of type SON-50 Nr397 with a microphone of type WK21 Nr 3490 produced by Sonopan.

Mathematical model of the experiment

Let us assume that the noise level y_{ijkl} derives from the i-th effect of the distance from the road (i=1,….7), j-th type of the area (j=1,2), k-th period (k=1,2) and l-th repetition (l=1,…,25). Moreover, let us assume that i,j,k,l-th observation of the noise level is derived from the three-factor linear model

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + e_{ijkl},$$

where:

μ – grand mean,

α_i – i-th effect of the distance from the road (factor A),

β_j – j-th effect of the area type (1-afforested, 2-non-afforested)(factor B),

γ_k – k-th effect of the measurement period (1-vegetation, 2-vegetative rest)(factor C),

$(\alpha\beta)_{ij}, (\alpha\gamma)_{ik}, (\beta\gamma)_{jk}$ – the effects of the second order interaction,

$(\alpha\beta\gamma)_{ijk}$ – the effect of the third order interaction,

e_{ijkl} – random error.

The analysis of the traffic noise volume at the national road 11 and the Umultowska street in Poznań was carried out according to the three-factor linear model. The measurements of the noise volume carried out in the Niestachowska and Witosa streets were interpreted according to the two-factor linear model. In the case of the Niestachowska street the first factor considered was changeability conditioned by the screening influence of the shrub-belt growing along the road. Whereas the first factor considered in the Witosa street was changeability conditioned by the polycarbonated acoustic screen. In both cases the period of measurements was the other factor considered.

Tukey's test [Ott 1984] was utilized to define the significance of differences of the level of noise between the two selected experimental objects.

RESULTS AND DISCUSSION

Basing on the variance analysis it can be stated that all the null hypothesis of the effects of major factors are rejected in favour of alternative hypotheses at the significance level of $\alpha = 0.01$ (Tables 1-4). The obtained results let us accept to a high probability that each of the factors specified in the experiment significantly differentiates the equivalent level of the traffic noise. It was found out that the values of the traffic noise level in the plant vegetation period are significantly different from the values obtained in the vegetative rest period (Tables 1-3) and that the traffic noise propagation in an afforested area differs from that of a non-afforested plot (Tables 1-2). Detailed results of the comparisons for the effects of the third order interaction (for national road 11 and Umultowska Street) are presented in Tables 5-6, while for the second order interaction (Niestachowska and Witosa Streets) in Tables 7-8.

Table 1. Analysis of variance for equivalent noise level in the vicinity of 11 Rout

Source of variable	Degree of freedom	Sum of squares	Mean of square	F-value	P-value
A	6	15078.6	2513.1	128.5	0.0000
B	1	10494.7	10494.7	536.8	0.0000
C	1	343.6	343.6	17.6	0.0000
A*B	6	783.9	130.7	6.7	0.0000
A*C	6	583.0	97.2	5.0	0.0001
B*C	1	42.1	42.1	2.2	0.1429
A*B*C	6	85.8	14.3	0.7	0.6247
Error	672	13137.9	19.6		
Total	699	40549.5			

Table 2. Analysis of variance for equivalent noise level in the vicinity of Umultowska Street

Source of variable	Degree of freedom	Sum of squares	Mean of square	F-value	P-value
A	6	12519.0	2086.5	167.2	0.0000
B	1	15310.2	15310.2	1226.7	0.0000
C	1	214.3	214.3	17.2	0.0000
A*B	6	338.3	56.4	4.5	0.0002
A*C	6	58.1	9.7	0.8	0.5890
B*C	1	1791.0	1791.0	143.5	0.0000
A*B*C	6	540.5	90.1	7.2	0.0000
Error	672	8386.8	12.5		
Total	699	39158.2			

Table 3. Analysis of variance for equivalent noise level in the vicinity of Niestachowska Street

Source of variable	Degree of freedom	Sum of squares	Mean of square	F-value	P-value
Plan cover	1	237.2	237.2	27.4	0.0000
Term	1	169.0	169.0	19.5	0.0000
Interaction	1	148.8	148.8	17.2	0.0001
Error	96	830.0	8.6		
Total	99	1385.0			

Table 4. Analysis of variance for equivalent noise level in the vicinity of Witosa Street

Source of variable	Degree of freedom	Sum of squares	Mean of square	F-value	P-value
Screen	2	3285.1	1642.5	96.2	0.0000
Term	1	278.8	278.8	16.3	0.0001
Interaction	2	77.4	38.7	2.3	0.1074
Error	144	2458.5	17.1		
Total	149	6099.7			

It was found out on the basis of multiple comparison tests that at the distance from 10 to 100m the volume of traffic noise is significantly lower in afforested areas compared to the non-afforested ones (Tables 5-6) both in the vegetation and plant vegetative rest periods. Moreover, it can be noticed that the level of traffic noise in the Umultowska Street for the non-afforested section is higher in summer than in winter. Corresponding dependences were not found for the national road 11 (Table 6).

The carried out investigations proved that the strongest influence of the afforestation on distribution of traffic noise occurred in the belt of approx. 50m width (Figs. 1, 2) both in the neighbourhood of the national road 11 and the Umultowska Street. The Umultowska Street afforestation influenced positively the level of noise in the vegetation season lowering it by 12-18%, while in the vicinity of the national road 11 by 5-12% (within the measurement points).Whereas during the vegetative rest period the level was reduced by 3-12% in the Umultowska Street and 6-12% in the neighbouring area of the national road 11.

Both in the vegetation and rest periods the traffic noise level measured directly in the Niestachowska street was very high and did not depend on the season since in both research periods the driving speed of the vehicles was similar and reached approx. 90km/h. The analysed belt of broad-leaved shrubs in the Sołacki Park lowered the value of the equivalent noise level by approx. 5dB only in the vegetation season (Fig. 3. Table 7).

The polycarbonated acoustic screen constructed in the Witosa street decreased the equivalent noise level by approx. 10dB (Fig. 4. Table 8) in both measurements periods with the same traffic parameters as found in the Niestachowska Street. The obtained level of sound screening is characteristic of this type of acoustic barriers.

Table 5. Equivalent traffic noise level in the vicinity of 11 Rout

Distance from road [m]	Vegetation period (July)			Rest period (January)			Research period comparsion (wegetation– rest period)	
	Non-forestry areas	Forestry areas	Difference	Non-forestry areas	Forestry areas	Difference	Difference for non-forestry areas	Difference for forestry areas
	(1)	(2)	(1) - (2)	(3)	(4)	(3) - (4)	(1) - (3)	(2) - (4)
10	90.6	86.5	4.2	87.4	78.9	8.6**	3.2	7.6**
20	86.3	79.8	6.5**	84.9	78.0	6.9**	1.3	1.7
30	85.8	76.7	9.1**	84.9	75.3	9.6**	0.9	1.4
40	85.2	76.2	8.9**	84.6	75.3	9.3**	0.6	0.9
50	85.1	74.2	10.9**	84.5	73.1	11.4**	0.6	1.1
100	79.9	72.8	7.1**	78.7	71.3	7.5**	1.2	1.5
200	71.7	67.6	4.1	73.0	68.6	4.4	-1.3	-1.0

**significant difference at level α=0.01

Table 6. Equivalent traffic noise level in the vicinity of Umultowska Street

Distance from road [m]	Vegetation period (July)			Rest period (January)			Research period comparsion (wegetation– rest period)	
	Non-forestry areas	Forestry areas	Difference	Non-forestry areas	Forestry areas	Difference	Difference for non-forestry areas	Difference for forestry areas
	(1)	(2)	(1) - (2)	(3)	(4)	(3) - (4)	(1) - (3)	(2) - (4)
10	87.0	72.0	15.0**	81.7	77.2	4.4**	5.3**	-5.2**
20	85.2	70.2	15.0**	77.4	74.8	2.6	7.8**	-4.6**
30	80.4	69.7	10.7**	75.3	71.7	3.6	5.1**	-2.0
40	77.0	67.9	9.1**	75.0	68.0	7.0**	2.0	-0.1
50	76.9	65.3	11.5**	73.0	65.5	7.5**	3.9*	-0.2
100	76.0	62.1	13.8**	72.7	63.7	9.0**	3.3	-1.5
200	73.6	60.8	12.8**	70.8	61.9	8.9**	2.8	-1.1

*significant difference at level α=0.05
**significant difference at level α=0.01

Table 7. Equivalent traffic noise level in the vicinity of Niestachowska Street

Distance from road [m]	Vegetation period (July)	Rest period (January)	Difference
Shoulder (in front of shrubs)	85.0	85.1	-0.2
20 (behind shrubs)	79.5	84.5	-5.0**
Difference „shoulder”-„20”	5.5**	0.6	

**significant difference at level α=0.01

Table 8. Equivalent traffic noise level in the vicinity of Witosa Street

Distance from road [m]	Vegetation period (July)	Rest period (January)	Difference
Shoulder (in front of baffle)	92.8	89.0	3.9*
4 (behind baffle)	82.4	81.7	0.7
20 (behind baffle)	82.0	78.4	3.6*
Difference „shoulder”-„4”	10.4**	7.3**	
Difference „shoulder”-„20”	10.9**	10.6**	

*significant difference at level α=0.05
**significant difference at level α=0.01

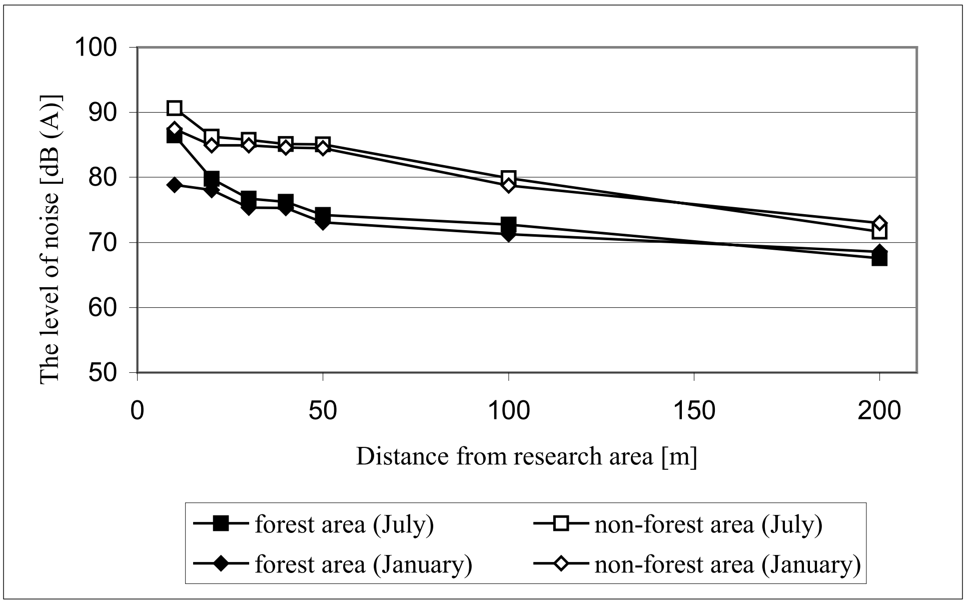

Figure 1. Equivalent traffic noise level in the vicinity of 11 Rout

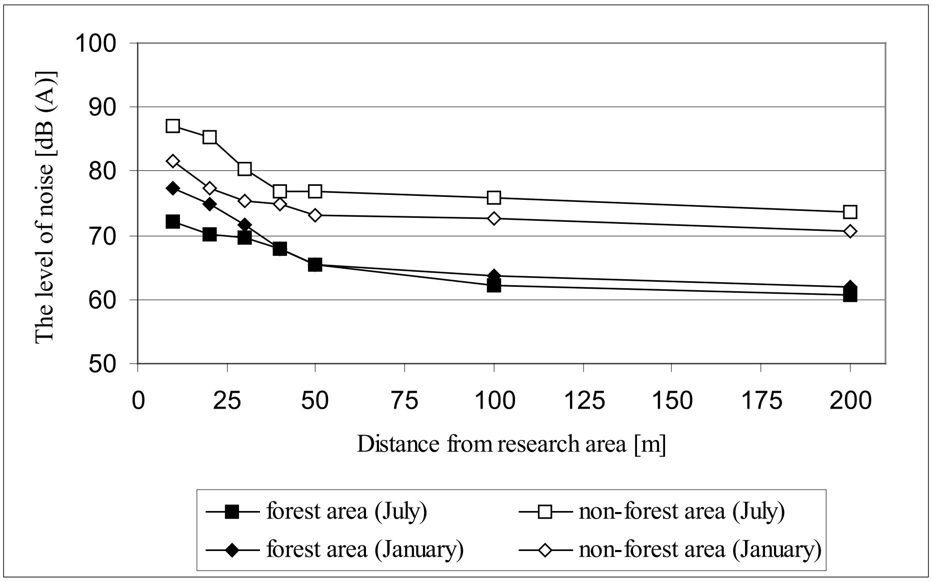

Figure 2. Equivalent traffic noise level in the vicinity of Umultowaska Street

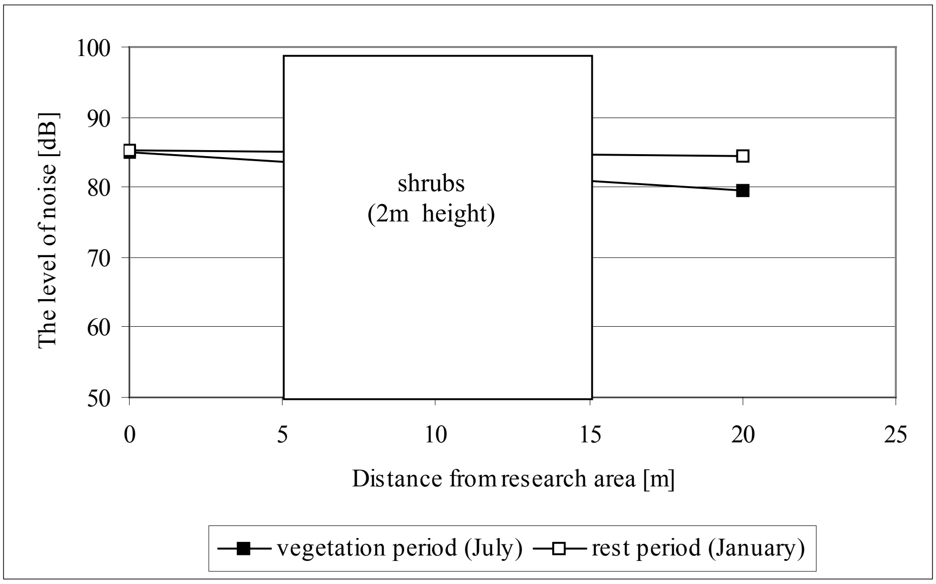

Figure 3. Equivalent traffic noise level in the vicinity of Niestachowska Street

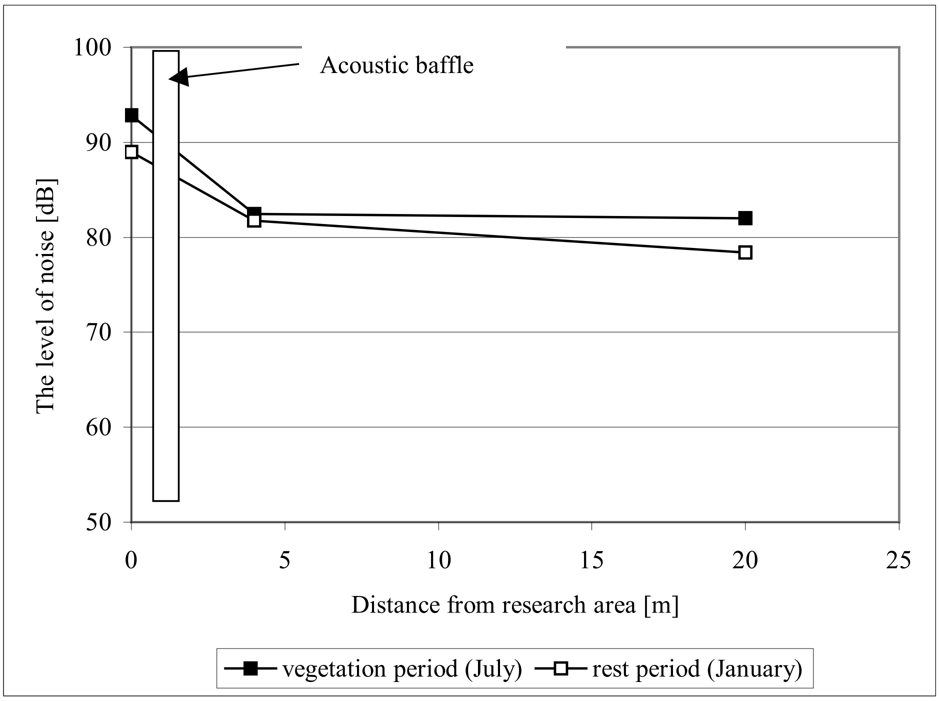

Figure 4. Equivalent traffic noise level in the vicinity of Witosa Street

CONCLUSIONS

1. Each of the selected factors (distance from the road. presence of afforestations. the season) significantly diversifies the equivalent traffic noise level. The most significant factor influencing noise propagation is the occurrence of the plant cover.

2. The equivalent noise levels were similar in both research periods in the afforestations situated in Złotniki. the national road 11 and Poznań. the Umultowska street. It results from the fact that the dominant species in the analysed afforestations was *Pinus sylvestris* L. The most significant equivalent level value decrease occurred in the 50m wide belt of the pine stand.

3. The approx. 30m wide pine stand reduces noise propagation both in winter and summer to a degree comparable to the polycarbonated acoustic screen.

4. The broad-leaved shrub-belt in the Sołacki Park decreased the equivalent noise level value (by approx. 5dB) only in the vegetation season.

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Rozporządzenie Ministra Środowiska z dn. 23 stycznia 2003 roku w sprawie wymagań w zakresie prowadzenia pomiarów poziomów w środowisku substancji lub energii przez zarządzającego drogą. linią kolejową. linią tramwajową. lotniskiem. portem (Dz. U. nr 35. poz. 308).

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