PROPAGATION OF SOUND FROM INDUSTRIAL SITES THROUGH BUILT-UP AREAS

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In 1981 the Dutch Ministry of Public Health and Environment issued a manual comprising a description of measuring techniques and calculation methods to be used for the control of industrial noise. The so-called "manual for measuring and calculating industrial noise" [1], also includes an analytical method for calculation of community noise levels around industrial sites. The method was also presented in a paper at Inter Noise 1983 [2].
One advantage of the manual relative to the already existing models as CONCAWE, OCMA and VDI [3], [4], [5] is that the manual offers a set of measuring techniques and calculation methods which are completely adjusted to each other. The manual deals with outdoor noise propagation only.

The sound propagation calculation method for industrial noise used in Holland is based on a number of damping terms pertaining to specific damping phenomena. The sound immission level L_i will be calculated as follows:

$$L_i = L_W - \Sigma D$$

L_W : sound power level of the source

ΣD : D_{geo} = damping due to spreading
D_{air} = damping due to air absorption
D_{ground} = damping due to ground absorption
$D_{scatter}$ = damping due to scattering and screening within the industrial plant
D_{screen} = damping due to screening
D_{refl} = damping due to reflections
D_{veg} = damping due to vegetation

D_{house} = damping due to screening and scattering by houses

All the terms we have mentioned are well defined in the Dutch model, except the term D_{house}.

This term represents the excess damping due to buildings in residential areas. This excess damping is mainly due to screening and scattering within the built-up area.
The main condition for the determination of this parameter is that the results of calculations should not depend on who executes the calculation and that extensive computer facilities and time consuming calculations are not necessary, so that the method can be widely used. Also, the method should not depend on subjective judgement.

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Sound propagation through built-up areas has been treated before [6], [7], [8]. Most of the publications deal with propagation through scattering objects. These studies do not include the influence of curved sound rays and of elevated sound sources and therefore result in a distance-dependent damping.

These methods are suitable for the calculation of traffic noise with noise sources close to the ground and at relatively short distances from the receiver (houses).

With regard to industrial noise and traffic noise at large distances (400 m and more), the above mentioned method is generally not applicable. For industrial sites the height of the sound sources is typically 5 m, in many cases more than 10 m (chimneys, cooling towers etc.).

In the calculation model as described in [1] the immission level has to be determined under down wind conditions; this is the so-called "standard immission level L_i". This means that the sound rays will bent downwards and impinge on the built-up site from above. Figure 1 shows this situation.

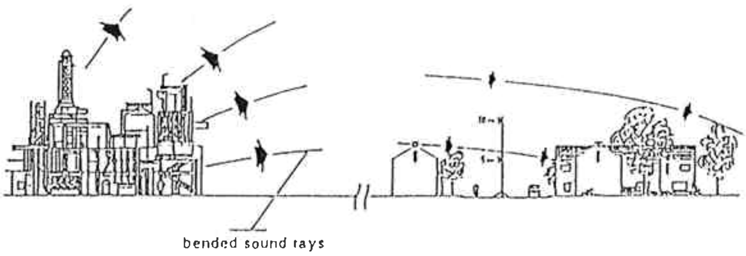
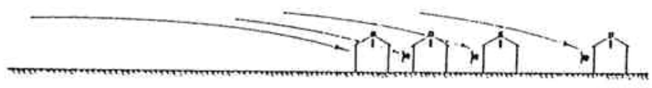


figure 1

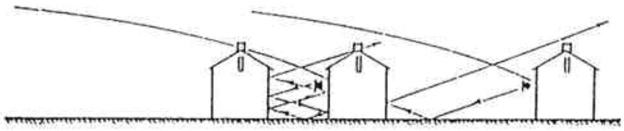
Due to scattering and screening the sound will spread in the residential area. As shown in figure 2 two different sound transmission situations can be found:

- the direct sound transmission, that reaches the receiver from above the roofs of the houses and through openings between the buildings or streets. This will be refered to as the direct component;

- the scattered sound is transmitted through reflection from buildings near the receiver. This will be refered to as the diffuse component.
  This component will come from all directions in built-up areas, and will highly depend on the configuration of the built-up areas.
  A higher density of scattering objects generally results in a higher sound level. Notice the resemblance with the indoor acoustics of big spaces.



direct field



scattered field

figure 2

The parameter D_{house} is defined as follows:

$$D_{house} = L_{i,0} - L_{i,house}$$

$L_{i,0}$: the immission level at a height of 5 m above the absorbing ground without any built-up area in the surroundings, the so-called "polder"-level under down wind conditions

$L_{i,house}$: the mean sound pressure level in the built-up area at the given location at a height of 3 m below the mean height of the buildings at a distance of 2 m from the nearest facade, also under down wind conditions.

The study is concentrated on finding the best fit relation between the term D_{house} and a small set of easily definable building parameters.

Parameters which we suspect to be of importance, bearing in mind that scattering is the main process, are:

- the mean distance between buildings;

- the mean facade length per area.

The direct component of the sound field depends on the screening by buildings. Because only the sound level at 3 m below the top of the building is of interest, this component will mainly depend on the average distance between buildings.

The parameters are corrected for the percentage of the area occupied by buildings, as this area does not contribute to sound propagation.

In figure 3 and figure 4 the spread in the individual points are given, together with the best fit.

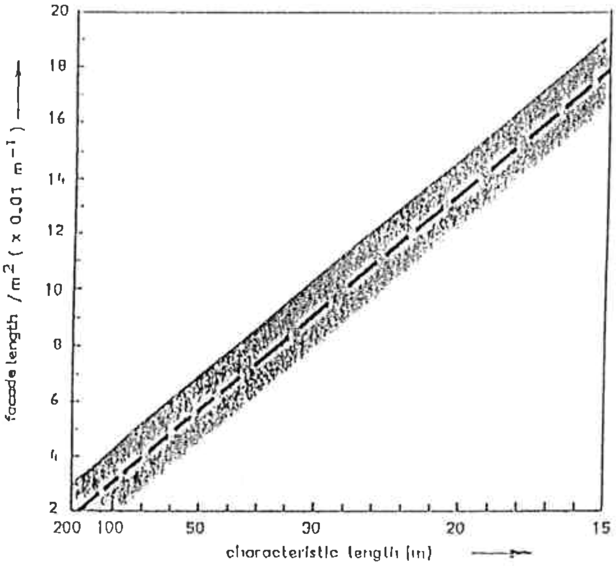


figure 5

However, it is found that both parameters are closely related.
This can be seen in figure 5, where the relation is given between the characteristic length and the facade length per square unit for various built-up areas, together with the spread in individual results. It can be concluded that one parameter will suffice.

The corrected building distance is chosen as the most useful one: that is the mean building distance within an area, multiplied by the percentage not occupied area. This parameter is named "characteristic length".
D_{house} can then be calculated as follows:

$$D_{house} = 2,2 + 3 \log \left(\frac{100}{L}\right)$$

L : characteristic length (m)

The magnitude of the diffuse component is directly related to the amount of scattering area present in a certain surface area, as can be seen in figure 2.

The relation between D_{house} and the above mentioned parameters is obtained as follows:

First a simple relation is supposed between D_{house} and each of the parameters:

$$D_{house} = a + b \log (\text{parameter})$$

The values of a and b are determined by fitting this relation to a series of measurement results. These measurements are performed in different types of urban areas, varying between semi-detached suburbs and densely built cities. 13 different types of urban areas are investigated. The results of one of these investigations are published in [9].

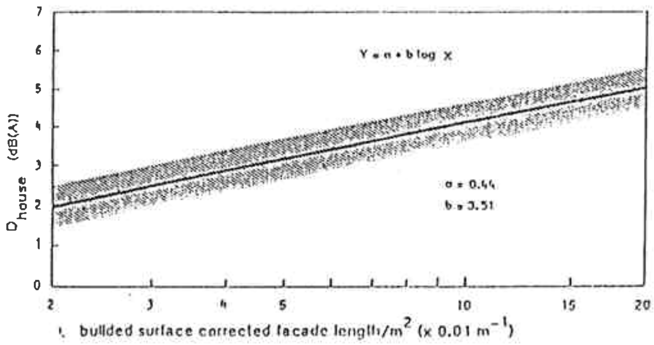


figure 3

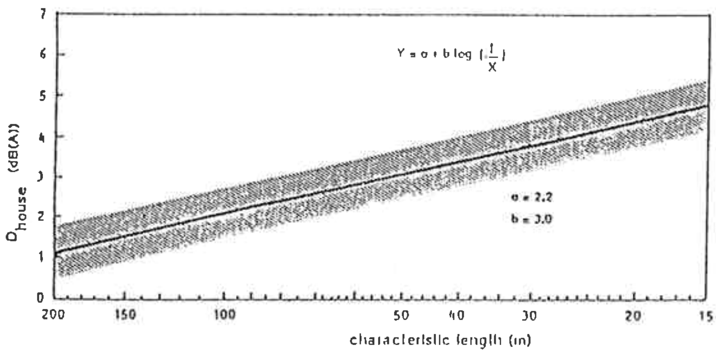


figure 4

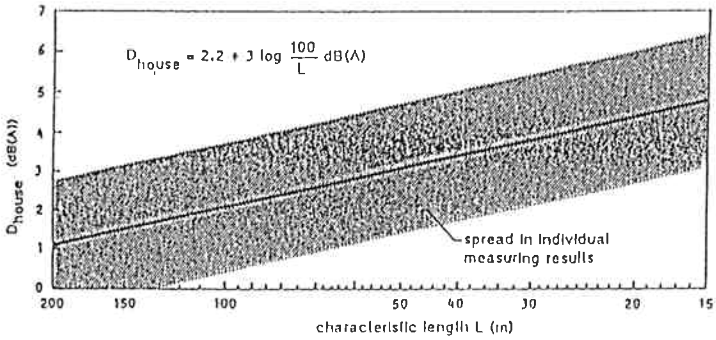


figure 6

Figure 6 shows this relation, together with the spread in individual measuring results. The characteristic length of approximately 150 stands for relative open built-up areas, the length of approximately 20 for densely built cities.

As can be seen in figure 6 the damping due to houses will vary between 1 dB for semi detached suburbs till 4,5 dB for densely built cities.
Coming to the end of this paper the proposed model will be discussed:

In order to reach such a simple calculation scheme certain concessions have to be made to the accuracy and general applicability of results. The immission levels in a built-up area, calculated with the parameter D_{house}, will define a value, that is as near as possible the same as the mean immission level to be obtained from measurements at many positions within this area. Local discrepancies between calculated levels and measured levels are, therefore, inherent to the method. For instance, direct behind buildings one will in general measure a much lower level.

Furthermore, this method can only be applied to areas, which are occupied by similar housing types of about the same height. That implies that incidental high apartment buildings and big open squares should be treated separately. When the immission position is in an open area and more than 100 m behind houses (as seen from the source), the term D_{house} will decrease to 0 dB(A).

The distance between the immission point and the noise source and the heights of the building and noise source should comply with the condition that propagation via down wind bended sound rays is possible.
In figure 7 the permitted and forbidden locations of the noise source with respect to the imission point are given.
It shows that at large distances (> 300 m) no restrictions with regard to source height need to be observed. Then the method will also be applicable to sources close to the ground.

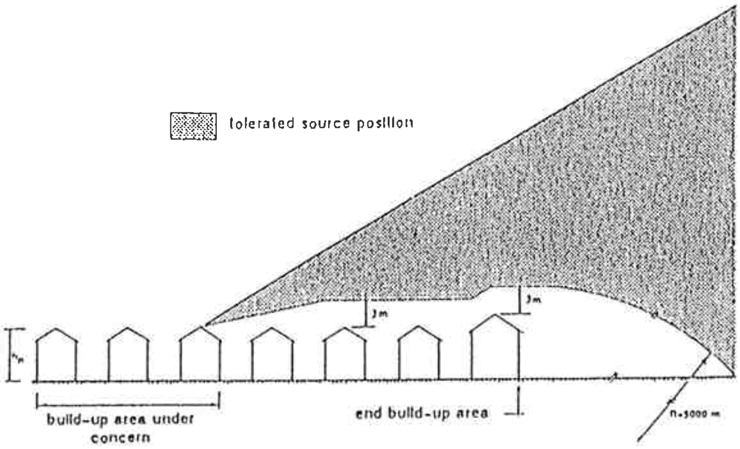


figure 7

It has been found that the accuracy in finding the characteristic length does not depend much on the grid-width and grid-orientation chosen.
In the study it is found that the damping is not dependent on the frequency. The dB(A)-value can be used for normal industrial and traffic sources, at least, when no dominant levels in the low frequencies occur.

The damping term D_{house} is also not dependent on the distance from the source and depends only little on the receiver height. Therefore the method can be used for almost all immission heights, except for the ground floors.

An example will be given to calculate the value of D_{house}.

The characteristic length L can be obtained as follows (see figure 8):

First of all the number of interceptions of the grid-lines by the buildings in the area has to be counted: here 83. Then the total length of the grid-lines should be taken, here 14 x 300 = 4200 m. The average building distance is therefore:

$$\frac{4200}{83} \approx 50,6 \text{ m}$$

The percentage none-building area is approximately 75%. So the defined characteristic length becomes:

$$L = 0,75 \times 50,6 = 37,9$$

Then the sound reduction in this area due to housing D_{house} becomes:

$$D_{house} = 2,2 + 3 \log \left(\frac{100}{37,9}\right) = 3,5 \text{ dB}$$

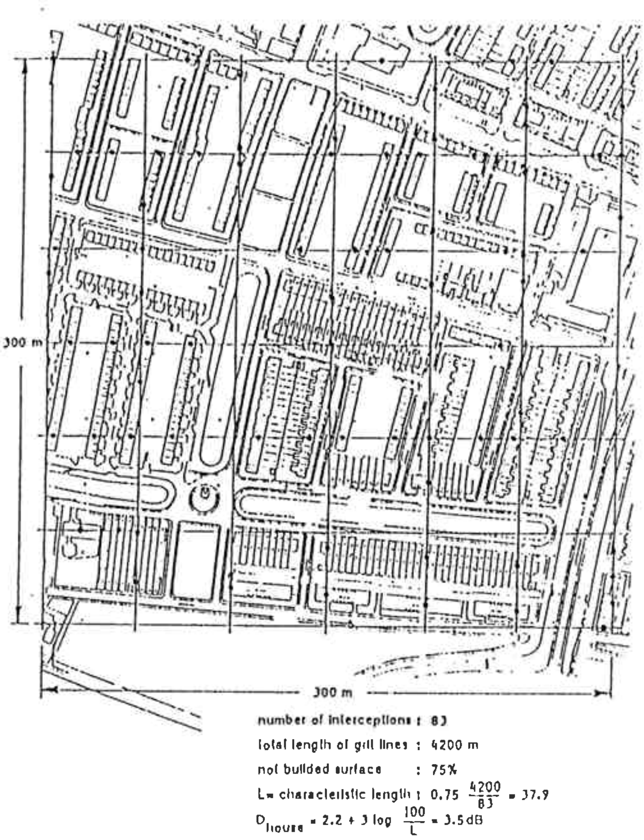


figure 8

To obtain the mean sound pressure level within the built-up area, 3,5 dB has to be subtracted from the sound level calculated under free field and down wind conditions.

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