014/81-09-07

CHARACTERIZATION AND JUDGMENT OF INDUSTRIAL NOISE.

Ymte Groeneveld

Instituut voor Milieuhygiëne en Gezondheidstechniek - TNO
(TNO Research Institute for Environmental Hygiene)
P.O. Box 214, 2600 AE Delft, The Netherlands

INTRODUCTION

Purpose. A project in the research program "Industrial noise" of the Interdepartmental Committee on Noise Abatement investigates the best way to characterize and judge industrial noise in the Netherlands. The primary purpose of this study was to get insight in experiencing sounds coming from industrial sites (and from shunting-yards of the Dutch Railways) in the Netherlands by neighbouring inhabitants. On basis of this study a policy will be stipulated with regard to legal norms for sound immission of industries in living areas.

Stating the Problem. In characterizing and judging industrial noise the ISO Recommendation 1996 (Assessment of noise with respect to community response) is often used. Completion and/or clarification of ISO/R-1996 was thought to be useful on several issues, of which the following have been the subject of this study:

a. drawing up dose-response relations for industrial sounds, with various annoyance and disturbance ratings as responses. The purpose of studying these relationships was to be able to use the (equivalent) sound level as a predictor for experienced annoyance and disturbance from it. Correlation and regression analysis have been performed in obtaining the dose-response relations.
b. further description of special sounds, such as impulsive and narrow-band sounds, for which the main question was whether for such sounds the characterization by means of penalties above the sound level (or the equivalent sound level) is adequate in all cases. This was studied by comparing continuous sounds with non-continuous sounds, e.g. impulsive sounds etc., via experienced annoyance and disturbance.

Table 1. Classification of industrial noise according to dimensions.

FREQUENCY-SPECTRUM / COURSE IN TIME	Tonal character narrow-band sound (1)	Noisy character non-narrow-band sound (2)
Continuous sound (A)	A1	A2
Fluctuating sound (B)	B1	B2
Intermittent sound (C)	C1	C2
Impulsive sound (D)	D1	D2
Impulsive sound with continuous character(E)	E1	E2

THEORETICAL BASIS

Characterization of Sound. ISO/R 1996 gives several qualifications for describing industrial noise, e.g. (as already mentioned) continuous, impulsive and narrow-band (= tonal) sounds. In our opinion there are two dimensions to distinguish, namely (1) the course of the sound in time and (2) the frequency distribution of the sound in the spectrum. Following this reasoning one can classify industrial sounds, based on the terms used by ISO/R 1996, as given in table 1.

Annoyance and Disturbance. For this explorative study use is made of two psychological response measures, annoyance and disturbance.

Annoyance can be circumscribed as a general feeling of discomfort due to sounds. Subjects can rate their annoyance as NOT ANNOYING, A LITTLE ANNOYING, ANNOYING and VERY ANNOYING.

Disturbance can be circumscribed as the quantitative sum of a number of activities in which one is frequently disturbed by sound. It results in a lineair (discontinuous) scale from 0 to 100.

METHOD

For this explorative survey sound level measurements and preliminary characterizations were made at 23 suitable industrial sites (18 industries and 5 shunting-yards), which satisfied i.a. the following conditions:

- the presence of audible industrial sounds
- the presence of a sufficient number of (at least 20) dwellings

Dose measuring. Because it was financially impossible to measure the sound level per dwelling it was necessary to choose the areas of dwellings so that the noise exposure in that area could be regarded to be fairly homogeneous. Because of too large differences it was insuperable in certain instances to divide a location in two or more sublocations with dose measures for each of these. Therefore the number of (sub)locations for industries as well as for shunting-yards became 26 and 7 respectively.

[illegible]

Table [illegible]: Classification of industrial [illegible]

[illegible]

THE [illegible] BASIS

Characteristics of [illegible] noise [illegible] continuous, impulsive and [illegible] there are two dimensions [illegible] (1) [illegible] time and (2) [illegible] in the spectrum [illegible]

[illegible]

METHOD

For this [illegible] and [illegible] measurements and preliminary characterisations [illegible] industrial sites [illegible] industries and [illegible]. The following conditions:

- the presence of [illegible] industrial noise
- the presence of a sufficient number of (at least 20) dwellings

Noise measurements. [illegible] to measure the noise level [illegible]

The measurements resulted in i.a. the three following sound measures:

1. the Leq (equivalent sound level) of the industry
2. a characterization according to table 1 of the type of sound
3. the difference between the Leq and the background noiselevel

Response measuring. Interviews were held with one adult occupant per dwelling before sound level measurements had taken place. The questions dealt with hearing industrial sounds, characterizing them and possibly being annoyed and/or disturbed by them. A total of 597 subjects were fully involved in the study.

Both annoyance and disturbance were determined for different situations, namely (1) a situation with opened windows and (2) another situation with closed windows. Besides this annoyance was measured in general. In this way three annoyance and two disturbance measures were generated. Annoyance (and disturbance) with open windows was expected to be higher than in the general situation, in which it was expected to be higher than in the situation with closed windows.

ANALYSIS

Clustering. A clustering was made in which the different sounds were classified (see table 2). In this clustering several originally distinguished types of sound were taken together to get enough respondents and (sub)locations in every cluster and to get a certain range in the sound level and annoyance variables for establishing a dose-response relation. The clusters with impulsive sounds contained at least impulsive sounds as the most important characteristic, and might also contain other types of sounds with it. Shunting-yards formed a seperate cluster with fluctuating-impulsive non-tonal sounds.

Table 2. Clustering of (sub)locations according to characterizations of different types of sound. The numbers in the cells before the slashes indicate the number of respondents in that cluster, while those after the slashes indicate the number of (sub)locations. The numbers between parentheses indicate clusters that are not analysed as seperate clusters (too small or not relevant).

number resp./(sub)loc.	tonality		total
	tonal(1)	non-tonal(2)	
continuous(A)	101/4	84/4	185/8
fluct/int(BC)	65/5	61/3	126/8
impulsive(D)	(21/2)	110/8	131/10
total	(187/11)	(255/15)	442/26
shunting-yards(RT)		155/7	(155/7)
TOTAL			(597/33)

Data manipulation. Analysis was done with the annoyance and disturbance determined per subject, that is to say at individual level. Besides this analysis was performed at aggregated level with aggregated data (per (sub)location) computed from the individual measured annoyance and disturbance. Per location a percentage of only very annoyed interviewed persons and a percentage of both annoyed and very annoyed persons was computed. Also a so-called Mean Relative Annoyance Score (MRAS) was computed per (sub)location, which was considered to represent the aggregated disturbance.

RESULTS

Dose-response relations. There were many possible dose-response relations, depending on the number of dose and response measures. Two dose measures were viewed as mentioned before. The number of response measures depended on the level where they were viewed: at individual level there were two measures for the disturbance and three for the annoyance, one for each discriminated situation. At aggregated level there were also two measures for the disturbance (for both situations), but six for the annoyance, namely two percentages as mentioned above for each situation. This resulted per cluster at individual level in
2 (dose measures) x { 2 (disturbance) + 3 (annoyance) } = 10
and at aggregated level in
2 (dose measures) x { 2 (disturbance) + 6 (annoyance) } = 16
possible dose-response relations. As there were 10 seperate clusters or combinations of clusters to analyse (see table 2) one might expect 100 different dose-response relations at individual level and 160 at aggregated level. About half of the dose-response relations were significant with regard to correlation and regression coefficients.

Representativity. Means of the various measures within the (combinations of) clusters could be computed, but could only be related to each other. They did not have any absolute value with respect to the Dutch industry. Some mean values will be given later.

The found relationships however, could be regarded as representative, and as such they were the most important. At this point the demands of the first issue (a) of this study, mentioned in the introduction, have been met, that is using the determined regression equations (or graphs) to find a certain amount of annoyance or disturbance at any (equivalent) sound level in any regarded cluster.

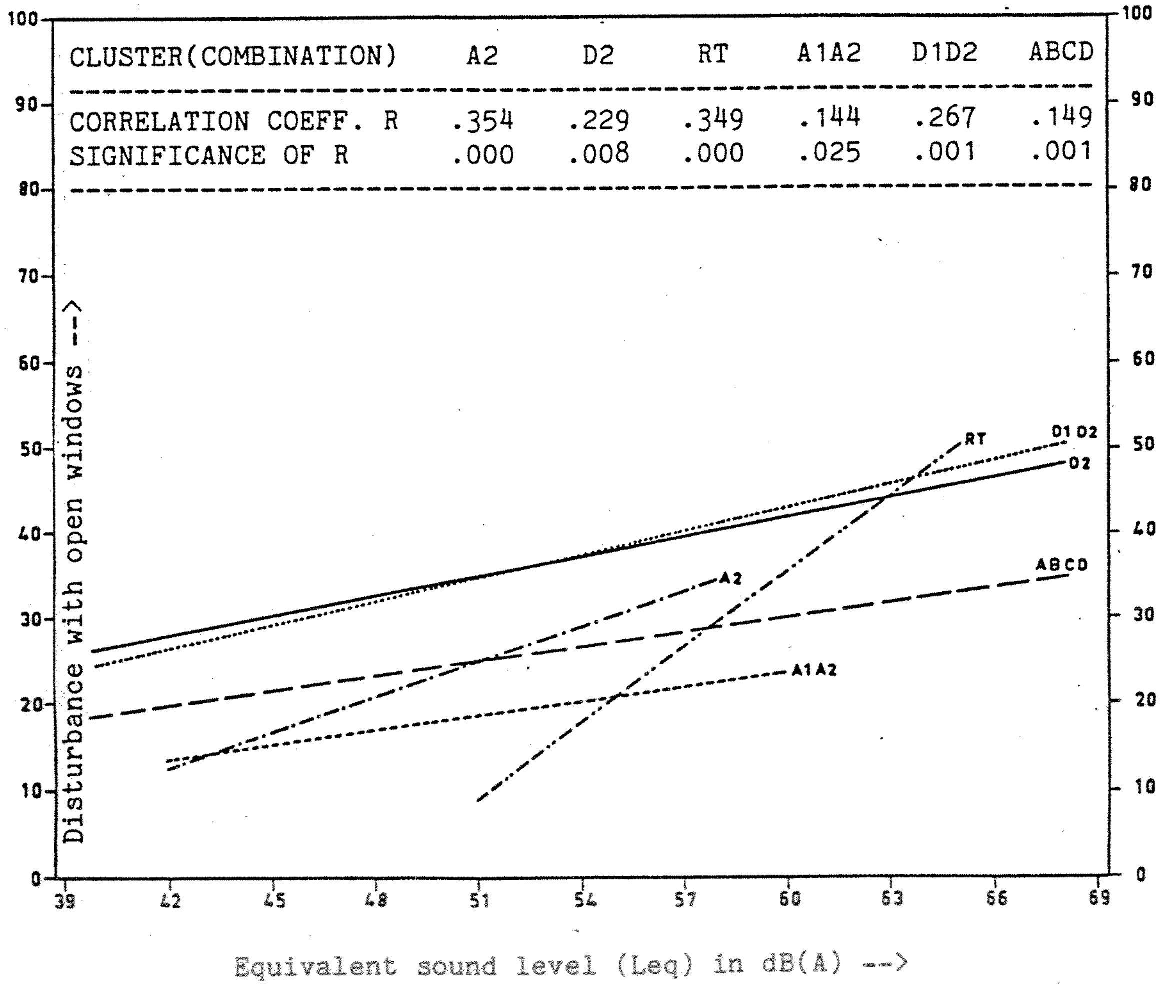
Interpretation. To meet the second issue (b), stated before, expressing the difference in measured response between different clusters as a difference in equivalent sound level, one has to compare the various dose-response curves between the clusters for the several response measures. This has been done for the most important ones, the dose-response relations between the Leq and the general annoyance, the annoyance with open windows and the disturbance with open windows respectively, all this mostly at individual level. All of this is treated in extension in the Dutch report of this study [1].

As an example one response measure will be viewed here with regard to the difference between several clusters (see figure 1.). The graph shows a higher curve from impulsive sounds (lines with "D") than from continuous sounds (lines with "A"). One might say: at a lower noise level from impulsive sounds an equal amount of disturbance can be expected as from a higher noise level from continuous sounds. This difference in Leq exceeds in general 10 dB(A), in some instances 20 dB(A), as can be seen from the graph.

Regarding shunting-yards, there can be seen, that at higher noise levels the disturbance equals that from impulsive sounds and at lower noise levels that from continuous sounds. Especially the strength of the relation (the correlation) is better with shunting-yards than with industries.

Some implications of this will be discussed after this.

Figure 1. Significant individual dose-response relations with significance and correlation coefficients from cluster(combination)s with the dose Leq and the response disturbance with open windows. See for the meaning of the codes table 2. (ABCD = all industries.)



CLUSTER(COMBINATION)	A2	D2	RT	A1A2	D1D2	ABCD
CORRELATION COEFF. R	.354	.229	.349	.144	.267	.149
SIGNIFICANCE OF R	.000	.008	.000	.025	.001	.001

CONCLUSIONS

The most important conclusions of this study, drawn by studying the significant dose-response relations, are:

- a mean Leq of the industry of about 53 dB(A) was found together with a mean score of about 25 on a scale from 0 to 100 for disturbance and a percentage of annoyance of about 46%. With shunting-yards these numbers are ± 58 dB(A), 27 and 41% respectively.
- annoyance (and disturbance) with open windows turned out to be highest, while with closed windows it turned out to be smallest, as expected.
- for other types of sounds than continuous sounds it is recommendable to award penalties above the equivalent sound level (Leq). For impulsive sounds a penalty of between 5 and 20 dB(A) is recommended, while for shunting-yards and fluctuating-intermittent sounds the penalty would be about half as large.
- nothing can be said about narrow-band sounds as compared to non-narrow-band sounds with regard to a possible penalty to be given due to insufficient information in the data.

EVALUATION

In general the noise exposure and noise annoyance correlate positively, however not high at <u>individual</u> level. This means that much variation with regard to the annoyance cannot be explained by the noise exposure of industries. Probably there are other factors, which influence annoyance. In the case of shunting-yards the (cor)relation is stronger and possible intervening factors probably play a less important role.

Another reason for suspecting intervening variables is the difference found between annoyance and disturbance: the latter, scoring lower, exists of disturbances which are known consciously as a consequence of the noise level, while the first response measure may also contain unconscious matters, which might intervene with the noise level and influence the experienced annoyance too.

Possible intervening factors could be: anxiety for (potential) dangers connected with industry, other types of annoyance than annoyance of sounds, such as annoyance of smell and so on. Other probable intervening factors, <u>not</u> connected with industry, are personal factors within the subjects and motivational factors, such as the living circumstances and the neighbourhood.

Another possible explanation for the weakness of the obtained relations and for some of the non-significant relations could be the small variation in the dose variables, due to measuring them only once per (sub)location in stead of once per respondent (dwelling).

REFERENCE NOTE

1. Y. GROENEVELD, "Karakterisering en beoordeling van industrielawaai," fase 3c, de mondelinge enquête, IMG-TNO, april 1981 (report D54).