TR-79-0053

ANNOYANCE OF THE RESIDENTS ON HIGH TRAFFIC STREETS TO NOISE AND AIR POLLUTION

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Medecine sociale et preventive,
volume 22, 1977, pp 108-115

Translated for EPA by

LITERATURE RESEARCH COMPANY

Annandale, Virginia

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How great is the extent and frequency of annoyances due to noise and air pollution in city conditions? Subjectively perceived annoyances which form the basis for setting limiting values were determined in a survey in the city of Zurich.

1. Introduction and Statement of the Problem.

Environmental hygiene no longer concerns itself at present with the demonstration of toxic effects of foreign substance in the water and air, but is extending to environmental conditions as well; which do not produce a pathological condition directly. Such environmental conditions such as, e.g., noise or air pollution, can nevertheless also lead either to physiological processes of change (e.g., like biochemical changes or central nervous system reactions), or they are perceived subjectively as disturbing.

Such annoyances due to environmental emissions of various types do, to be sure, impair the physical and mental well-being and therefore - in accordance with the definition of health from the WHO - also represent an impairment of health. In order to be able to determine health injuries caused by the environment, criteria for evaluating the annoyance are also necessary. In the course of determining the annoyance, a number of technical measurement problems result, since it is not possible to rely solely on physiological parameters or to perform only direct surveys concerning a given disturbing factor. Rather, attention must be paid to the fact that judgments concerning various disturbing factors always have to be compared

with each other. In addition to such judgments, surveys concerning direct reactions and changes in the behavior also provide important pointers from which one can draw conclusions as to what extent an intended behavior is impaired or obstructed.

Additional factors which can influence the type and intensity of an annoyance are habituation and sensitization; in addition, generalization and transfer effects have to be taken into consideration as well such as those which can be caused by an opinion with respect to a given disturbing factor, as well as by its general social significance. These complex relationships result in the fact that, e.g., the annoyance caused by traffic noise cannot be equal for all of those effected; for example, in the case of young people and of old people or in the case of residents of different quarters, one must expect different evaluations and reactions. In this connection, the problem of forming representative groups arises - particularly with respect to the determination of acceptable stresses and of limiting values.

In previous studies concerning the annoyance due to street traffic noise, the relationships between the number of disturbed persons and the noise levels measured in each case were relied upon. Such "dose-effect relationships" do provide valuable bases for the evaluation of the extent of the disorders; nevertheless, difficulties always result in the case with the question as to what noise level can still be considered acceptable for what percentage of disturbed people. For such evaluation, marginal conditions such as the attitude with respect to the source of disturbance as well as the influence of additional disturbing factors have to be taken into consideration as well. In addition, this perceived annoyance, if possible, would also have to be tested with other methods (e.g., physiological studies).

In the present study, the annoyances due to two of the obviously most important disturbing factors of street traffic - namely noise and air pollutions - are compared with each other, the influences caused by the

local situation being taken into consideration as far as possible. The residents of streets in four quarters with different traffic loads and construction density were surveyed. The survey was made within the framework of a research project concerning air pollution in streets supported by the Swiss National Fund [Ref. 8].

2. Description of the Quarters.

The streets which were studied were located in older, relatively centrally located quarters of the city of Zurich. Three of the quarters (Wehntaler Street, Winterthur Street, and Long Street), the residences are located in the direct vicinity of highly frequented streets; the Oerlikon quarter was selected as a comparison quarter with purely local traffic.

Figure 1 shows the four quarters with statements concerning the average traffic frequencies at day and at night in a schematic presentation. They can be characterized in the following way with respect to construction and utilization:

- Oerlikon (OE): residential quarter with multi-family houses as well as small single-family houses in gardens; age of the houses: 20 to 40 years; the overall random building with a great deal of green is located between two large arterial streets.

- Wehntaler Street (WE): residential quarter along an arterial street; multi-family dwellings of a similar construction, all approximately 40 years old; random method of building with a great deal of green. In this quarter, two groups can be distinguished: dwellings which are located directly on the street and dwellings which are somewhat set back behind this row of houses; these two groups are always designated below as "front" (WE_v) or "rear" (WE_h).

- Winterthur Street (WI): residential quarter - partially mixed with

office rooms - on an arterial street with a street car line; multi-family houses of similar construction, all built approximately 50 to 60 years ago; dense method of construction, no green space.

- Long Street (LA): residential and business quarter with office rooms and restaurants. Multi-family houses usually are older construction type, partially with poor structural conditions; very dense construction, no green space.

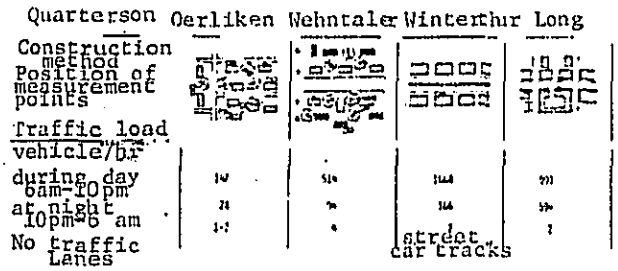

Figure 1. Schematic representation of the four quarters, Wehntaler Street: formation of two groups:

v = "front" (houses on the street)
h = "rear" (rear houses)
● = noise (continuous measurement for 24 hours)
O = noise (30-minute-measurements)
— = gaseous air pollution (30-minute-measurement)
▨ = floating dust (long-term measurements for one year).

The noise stresses measured in the four quarters are summarized in Table 1. The measurements were taken on two days each in the summer and in the winter for 24 hour periods each; in three quarters additional short-term measurements for 30 minutes each were taken so that an average stressing of the entire quarter could be determined. The three through streets are typical examples of highly travelled city streets with high noise levels,

while Oerlikon can be designated a relatively quiet city residential quarter.

Table 1.

NOISE STRESS IN THE FOUR QUARTERS, AVERAGE VALUES OF FOUR CONTINUOUS MEASUREMENTS EACH FOR 24 HOUR PERIODS. IN PARENTHESES: RANGE OF THE 30-MINUTE SAMPLES AT ADDITIONAL MEASUREMENT POINTS (see Figure 1).

Noise stress	Quarters				
During the day 6 am – 10 pm					
At night 10 pm – 6 am					

Table 2.

AIR POLLUTION IN THE FOUR QUARTERS, AVERAGE VALUES OF THE GASEOUS COMPONENTS (30-MINUTE-SAMPLES, MEASUREMENT DAYS IN THE SUMMER OF 1975 AND IN THE WINTER OF 1976/76) AND OF THE FLOATING DUST (WEEKLY SAMPLES FROM OCTOBER 1975 TO SEPTEMBER 1976). POSITION OF THE MEASUREMENT POINTS: see Figure 1.

Components	Quarters				
Carbon monoxide ppm	0.8	1.6	1.6	2.2	12.5
Nitrogen monoxide ppb	12	24	41	-	291
Nitrous dioxide ppb	21	21	29	-	51
Nonmethane hydrocarbon in ppm	0.2	0.2	0.4	-	2.8
Sulfur dioxide in ppb	11	11	13	-	14
Formaldehyde in ppb	9	9	10	-	13
Floating dust in $\mu g/m^3$	19	-	72	-	96

The most important data concerning the air pollution measured can be seen in Table 2. For the gaseous components, 20-25 simultaneous measurements each were taken at various measurement points in the summer and in the winter in each quarter. The floating dust was measured throughout a year at a measurement point in Oerlikon, on Wehntaler Street, and on Long Street. The

measurement methods, the results of additional measurements, and their hygienic evaluation have already been published in a detailed form elsewhere [Refs. 1 and 6].

3. Conducting the Survey.

The survey was carried out using a written questionnaire. All of the residents in a segment of approximately 1 km were questioned on Long Street, Wehntaler Street, and Winterthur Street; on Long Street, the residents of the first houses on the side streets were questioned in addition. In Oerlikon, the residents of ten streets of the quarters were included in the study. In households with several adult family members, only one person was included in each case so that the persons surveyed would be distributed as uniformly as possible among the age groups and sexes.

Out of a total of 1,958 persons who were addressed, a total of 1,297 responded, which corresponds to an overall return rate of 66%. Distributed by quarter, this rate was 71% in Oerlikon, 67% on Wehntaler Street, 75% on Winterthur Street, and 50% on Long Street.

4. Comparability of the Quarters from a Social Viewpoint.

The age and social structure of the residents and their average duration of residence can be designated the most important social structure characteristics.

The age structure of the four quarters which were studied differ significantly in that the structurally oldest quarter, Winterthur Street and Long Street, are also markedly over age with respect to the population. The percentage of persons over 60 years old who were included in the survey therefore differs in the individual quarters:

- Oerlikon 28%
- Wehntaler Street 21%
- Winterthur Street 40%
- Long Street 42%.

As a comparison with this, the percentage of persons over 60 in the total adult population of the city of Zurich is 30% [Ref. 7].

The social structure of the residents in the various quarters differs only slightly, but not significantly. The occupational structure and the income conditions in the four quarters are definitely comparable. The majority are members of the lower middle class (workers and employees with an average income of approximately 3000 Francs).

Certain differences are found only in school training. The majority of the men in all the quarters went to secondary school and finished an occupational training. In this, the residents of Long Street deviated slightly downward (23% of the males had visited only grammar school), and those of Winterthur Street deviated slightly upward (34% of the males had attended intermediate school).

The percentage of persons not employed (housewives, pensioners) among the persons surveyed, which can be significant for the annoyance due to emissions, is likewise not significantly different, since the high percentage of pensioners on Long Street and Winterthur Street, in Oerlikon and on Wehntaler Street is compensated for by a higher percentage of housewives.

In addition, in the case of the duration of residents, no significant differences were found between the quarters. Since quarters of older construction were involved in all of the cases, more than half of the residents have been there for more than ten years, while approximately 25% have lived there for four to ten years and 25% for less than three years.

In all, it can be stated that the four quarters do not differ essentially in their social structure so that marginal social conditions should not have any different influence on sensitivity to noise and air pollution.

5. Perceived Annoyance due to Noise and Air Pollution.

Table 3 shows a summary with the data concerning the frequency of disturbances due to traffic noise referring to the most disturbed time of day. The persons surveyed indicated that time during which they felt most disturbed; when this was done, only one mention was possible.

Table 3.

FREQUENCY OF THE DISTURBANCE DUE TO TRAFFIC NOISE REFERRED TO THE MOST DISTURBED TIME OF DAY

Quarter	n	Rarely or never disturbed %	Frequently disturbed %	Most disturbed time of day for frequently disturbed person: all frequently 00-04 %	04-09 %	09-19 %	19-22 %	22-00 %
OE	375	42	16	16	18	26	40	
WE_h	91	18	45	2	27	27	44	
WE_v	248	6	67	8	26	28	39	
WI	236	5	71	18	35	19	29	
LA	241	6	77	3	10	15	72	

It was found that with the exception of Oerlikon, a large portion and in the case of those living directly on the large streets, even the majority of the residents felt disturbed frequently. To be sure, the time of day differs at which the persons surveyed felt particularly highly disturbed. In general - with the exception of Winterthur Street - the highest proportion of disturbed people is found at night; this deviation is significant, to be sure, only on the rear at Wehntaler Street and on Long Street.

In addition to the frequency of the perceived disturbance, its intensity was also determined. This extent of the perceived disturbance was measured by means of self rating on a noise thermometer which has already been tested several times [Ref. 9] using a scale range from 0 to 10. When this was done, the classification on the level 0 indicates that the noise is not disturbing

at all, while the level 10 at the top end of the scale indicates that the noise is intolerably disturbing.

Table 4 shows a survey concerning the extent of perceived disturbances, during the day and at night. As in the case of the frequency, it is also found here - with the exception of Winterthur Street - that there is a larger percentage of highly disturbed people at night compared to day.

Table 4.

EXTENT OF DISTURBANCE DUE TO TRAFFIC NOISE REFERRED TO THE MOST DISTURBED TIME OF DAY. CLASSIFICATION OF THE RATING ON THE NOISE THERMOMETER: 0-3 = WEAK, 4-7 = MODERATE, 8-10 = HIGH.

Quarter	Most disturbed people during day				Most disturbed people at night			
	Total	Extent of disturbance			Total	Extent of disturbance		
	N	%	%	%	N	%	%	%
OE	228	63	30	7	148	69	24	7
WE$_n$	40	28	52	20	31	32	38	31
WE$_v$	256	12	52	36	93	3	29	68
WT	142	4	39	57	66	9	39	52
LA	67	12	49	39	126	6	39	55

Figure 2 shows these data as a function of the corresponding noise values.

The relationships between the measured noise values - expressed as the average noise level L_{50} and the equivalent continuous sound level L_{eq} - and the extent of the disorder are clearly higher during the day than at night. To be sure, neither the L_{50} nor the L_{eq} values show a clear relationship to the proportion of highly disturbed persons. The following is striking:

- At equivalent noise levels (both L_{50} as well as L_{eq}), 39% are highly disturbed on Long Street during the day, but 57% are highly disturbed on Winterthur Street; in addition, at the same L_{eq} range in Oerlikon, 7% are highly disturbed, while 20% are highly disturbed on Wehntaler

Street (rear); the divergences at night are even clearer in this case: Oerlikon, 7%, and on Wehntaler Street (rear) 31% at approximately equivalent L_{50} or L_{eq} values.

- The percentage of highly disturbed people at night on the Wehntaler Street (front), on Winterthur Street and on Long Street are on the same order of magnitude, although the noise levels differ markedly, measured at these locations; even at L_{eq} values of 61-65 dB(A), over 50% of the residents are highly disturbed - nevertheless, the percentages do not become greater as these noise levels increase .

- The percentages of persons highly disturbed at night on the main streets can be designated particularly high. Of those who designated the noise as "intolerable" (Thermometer - level 10), e.g., 75% of the people on Long Street indicate night as the most disturbed time.

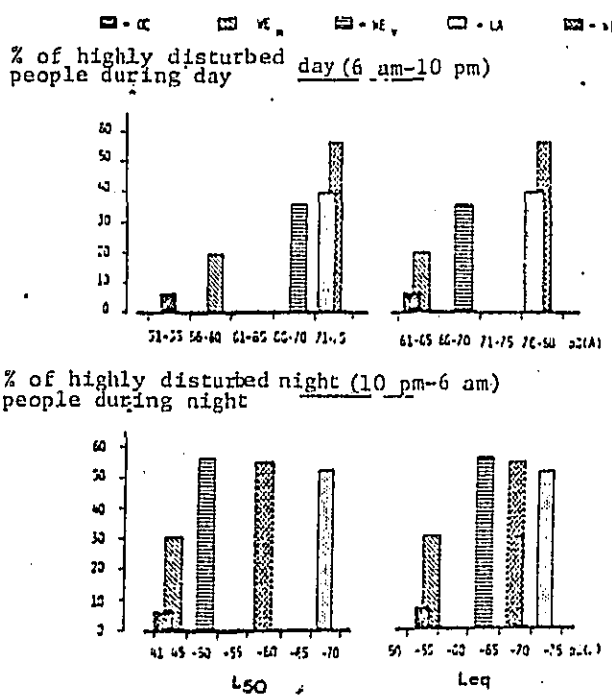

Figure 2. Noise stress and perceived annoyance - during the day and at night.

Figure 3. Comparison of the noise stress and the perceived noise - during the day and at night.

The sensitivity at night is also clear in Figure 3: although the L_{eq} values are lower at night (particularly clearly in WE_h), the percentage of highly disturbed people on Wehntaler Street and Long Street increase markedly.

Figure 4 shows the tendency of the number of highly disturbed persons on the traffic frequency. A relatively good relationship resulted during the day; the difference in the percentage of highly disturbed people between Winterthur Street and Long Street could be related in part with the different traffic frequencies. On Winterthur Street, therefore, occasional disturbances due to the street car also had to be taken into consideration, which was not determined in the course of the survey. At night, on the other hand, a similar picture results here as in the case of the noise measurements; as soon as an average of 100 vehicles/hour (Wehntaler Street), over 50% are highly

disturbed; this level remains constant and is not higher even in the case of approximately 600 vehicles/hour on Long Street.

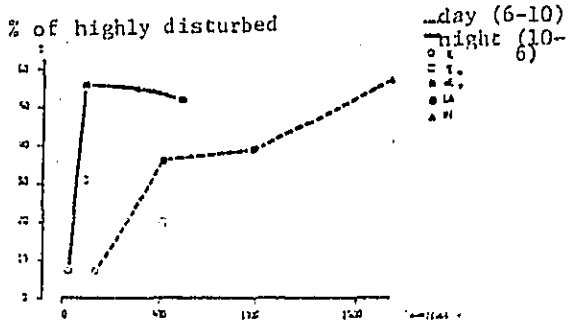

Figure 4. Disturbance due to the noise as a function of the traffic frequencies, during the day and at night.

As in the case of traffic noise, frequency and the intensity of the perceived disturbance was determined in the case of the air pollution as well, the intensity being measured on a thermometer by subjective rating in this case as well.

Table 5 shows the extent and frequency of the perceived disturbance due to air pollution.

Table 5.

FREQUENCY AND EXTENT OF PERCEIVED ANNOYANCE DUE TO AIR POLLUTION. PERCENTAGE OF "FREQUENTLY" AND PERCENTAGE OF "HIGHLY" DISTURBED PERSONS (SCALE POINT 8-10).

Quarter	N	Frequently disturbed %	Highly disturbed %
OE	480	13	7
WE_h	97	25	12
WE_v	263	45	26
WI	248	73	50
LA	209	64	47

The subjective disturbance does not correspond very well with the actual air pollution which is highest on Long Street. This is a function of two factors: on the one hand, the gaseous air pollution (CO and NO_2 portions) can be perceived only partially by the effected persons, and on the other hand, we were not able to find a very strong correlation between the annoyance due to noise and due to the air, so that it has to be assumed that the residents on a noisy street immediately assume as well that the air is bad too.

In all, the following correlations resulted between the annoyance measurements:

- Frequency of the disturbance to the air pollution and frequency of the disturbance due to noise: $\gamma = 0.78$

- Extent of the disturbance due to the air pollution and extent of the noise: $\gamma = 0.72$.

This relationship is also shown in Figure 5. It can be seen from this figure that, on Wehntaler Street, in spite of relatively low exhaust gas concentrations, the number of persons disturbed by the air pollution is already two to three times higher than Oerlikon; in addition, approximately an equal number of residents on the Winterthur Street complained of the air pollution as on Long Street, although the concentrations of dust and gaseous air pollution there are approximately twice as high. The fact that definitely high correlation values resulted between the perceived disturbance due to the noise and the disturbance due to the air pollution permits the conclusion that the disturbances due to the air pollution are highly dependent upon the extent of the disturbance perceived due to noise.

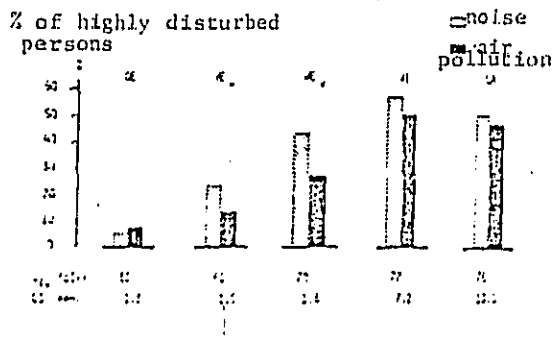

Figure 5. Comparison of the perceived annoyance due to noise and air pollution.

6. Social and Spatial Influences.

The strongest variable influence on the perceived disturbance due to noise and air pollution is age (Table 6):

Table 6.

THE EXTENT OF THE DISTURBANCE DUE TO NOISE AND AIR POLLUTION AS A FUNCTION OF AGE. EVALUATION USING THE "THERMOMETER" (SCALE RANGE 8-10 = HIGHLY DISTURBED).

Age group (in yrs.)	Overall percent of highly disturbed persons- due to noise - air pollution		
< 30	241	16	22
30 - 50	410	23	32
> 50	634	34	37

The more strongly perceived annoyances by the older people is found primarily in the different reactions as well. For example, the older people are frightened significantly more frequently and take sleeping agents more frequently against noise (see Ks section 7).

No influence of the duration of residence can be recognized on the frequency of the disturbances due to noise - connected with a possibility of becoming accustomed or increasing sensitization.

The spatial influences were all of slight significance with respect to the perception of noise. A weak influence of the floor in the house was determined: in the case of residents on the ground floor and the second floor, the number of highly disturbed people was slightly lower than the case of the people residing on upper floors.

The position of the room with respect to the street had a certain influence on the perceived disturbance due to the noise: the percentage of "highly disturbed persons" due to noise is significantly higher in the cases of people surveyed where their living room or bedroom faces the street. To be sure, this difference is valid only for the residences directly on the street. The extent of annoyance due to air pollution, on the other hand, is not dependent upon the location of the room.

7. Effects and Reactions.

Sleep disorders are particularly significant among the effects of noise injurious to health. As can be seen from Table 7, between 35 and 40% complain of disorders of recreational functions (sleeping, relaxation) in the highly stressed quarters. Approximately a third of the residents in these quarters also perceive disturbances of communication functions. These disturbances are somewhat lower on Long Street than on Wehntaler and Winterthur Streets, although the noise level is on the same order of magnitude. This corresponds to the differences already found in the case of the extent of the disturbances - particularly during the day between Long Street and Winterthur Street (see Table 4).

Table 7.

DISTURBANCES OF VARIOUS RESIDENTIAL FUNCTIONS DUE TO NOISE.

Residential functions	% of frequent disturbances				
	OE %	WE$_h$ %	WE$_v$ %	WI %	LA %
Recreative functions (sleeping, recreation)	57	21	39	35	40
Communication functions (radio, TV, telephone)	5	20	30	30	22
Productive functions of (work)	1	4	12	19	15

Table 8.

REACTIONS TO THE PERCEIVED NOISE DISTURBANCE.

Reactions	% of frequent reactions				
	OE %	WE$_h$ %	WE$_v$ %	WI %	LA %
Taking sleeping tablets and tranquilizers	20	27	28	23	31
Use of "Ohropax" or uppers	7	13	17	21	20
Closing windows (during the day)	11	21	60	69	57
Improved home insulation	2	11	13	29	24

In the reactions, two types can be distinguished in principle: those which refer to better adaptation as an alternative than to moving away. Table 8 shows the extent of such "adaptation reactions". In addition to the widespread reactive habit of closing the windows, consumption of sleeping agents, and the use of Ohropax appear above all the most frequent. These statements correspond in general with the percentage of "highly" disturbed people in the corresponding quarters. In the case of the people over 50

years of age who have a higher percentage of "highly" disturbed people, the percentage of those who take sleeping agents because of noise also increases to 28% (compared to 21% in the case of 30 to 50 year old persons, and 9% in the case of persons younger than 30 years).

Clear differences between the quarters are also found in the statements concerning intentions to move away (see Table 9). Classification according to age group shows that the younger people think of moving away sooner than the older people. The reasons for moving away can differ; essentially, the fact remains that for the young people, the residential situation does not have such a definitive character as a rule. The older people probably have a closer bond with their domicile and therefore react more "individually resisting" to the perceived disturbance by protecting themselves from the disturbances of noise using sleeping agents or Ohropax. These differences are greatest on Winterthur Street: intentions to move away because of noise were expressed by 57% of those younger than 30, but only 26% of those over 50 years of age.

Table 9.

INTENTIONS TO MOVE AWAY BECAUSE OF NOISE AND AIR POLLUTION (MULTIPLE MENTIONS POSSIBLE).

Quarters	n	% of residents with intention of moving away because of noise	air pollution
OE	451	7	6
WE$_n$	97	17	8
WE$_y$	263	12	14
W	248	15	17
ZA	229	16	12

8. Conclusions.

The following can be stated in conclusion: of the residents of highly

travelled through streets, approximately two/thirds are disturbed "frequently" by the noise and air pollution, and approximately half are "highly" disturbed; the percentage of persons who are disturbed only "weakly", "rarely", or "never" is less than 10%. In the comparison quarter of Oerlikon with only local traffic, on the other hand, the percentage of "highly" disturbed persons is only 7%, while approximately two/thirds are disturbed only "weakly" and 40% "rarely" or never". In general, the disturbances are perceived more markedly at night than during the day, particularly by the old people. This is shown also in the different reactions to the noise disturbances: approximately a third of the residents of the through streets complain of sleep disturbances, and approximately the same number take sleeping agents or tranquilizers; and approximately 25%, the communication functions are disturbed, and approximately a third have intentions to move away because of noise or air pollution. In the comparison quarter of Oerlikon, the percentages of these disturbances and reactions range from 5 to 10%.

If one compares the frequency and extent of the annoyances perceived with the measured noise levels or the concentrations of dust and gaseous air pollution, then no uniform picture results in the four quarters which were studied. For example, the percentage of "highly" disturbed people in the case of the residents of the rear house row of Wehntaler Street is essentially higher during the day as well as night than in Oerlikon, although approximately the same stresses exist due to noise and air pollution. The location in the direct vicinity of the through street probably influences the judgments, even if the noise and exhaust emissions are clearly reduced by the front rows of houses. Additional disturbances due to the heavy traffic - such as increased danger of accident, difficulties in crossing the street, separation of a previously uniform quarter - therefore probably have an influence on the perceived disturbances due to noise and air pollution. On the other hand, the residents in Oerlikon - occasionally the owners of single family houses with gardens of their own - tend to have a more positive relationship to their quarter so that, in spite of the noise levels which can still be

designated as relatively high for a residential quarter, the percentage of "highly" disturbed people remains below 10%.

An "influence of the quarter" of a different type probably influences the judgment of the persons surveyed on Long Street: the clearly lower percentage of persons "highly" disturbed during the day as well as the lower disturbances of communicational functions than on the Winterthur Street which is approximately equally heavily travelled, is probably related to the fact that on Long Street, due to the numerous sources of noise belonging to the quarters such as businesses and restaurants, a generally higher level of noise is accepted, and that a large portion of the residents are involved occupationally with Long Street. In all, these results showed that conclusions about the number of disturbed persons cannot be made without difficulty based on the measured level of noise; the specific situation of a quarter likewise has to be taken into consideration.

A relatively good relationship resulted during the day between the number of "highly" disturbed persons and the traffic frequency in each case. At night, on the other hand, even at an average of 100 vehicles/hour, the proportion of approximately 50% of "highly" disturbed people was reached, which did not increase further even at an average of 600 vehicles/hour. Additional indications that the traffic frequency can be a suitable parameter for evaluation of the disturbing effects have been provided by studies performed in Sweden [Ref. 5]; in the course of this, it was found that the best correspondence was with the number of trucks. To be sure, the extent to which these relationships can be universalized must await further studies.

With respect to the determination of limiting values, the differences in the disturbances perceived during the day and at night, which occasionally differ considerably, have to be taken into particular consideration. At night, the percentage of "highly" disturbed persons is overall more frequent than during the day - in contrast to the results of the survey in the city of Vienna, where more people were annoyed during the day by noise than at

night [Ref. 4]. In addition, the Viennese study also showed good correlations between the statements concerning annoyances due to noise and air pollution, the noise likewise proving to be the decisive disturbing factor in this case as well.

Comparison of the results in the four municipal quarters with the questions asked within the framework of the study "living in new construction" [Ref. 9] as well as of the "aviation noise study" [Ref. 3] concerning disturbances due to street traffic noise shows the following: in these two surveys, approximately 10% were "highly" disturbed during the day at L_{50} values of 56-60 dB(A) - i.e., approximately the same as in Oerlikon; at 66-70 dB(A), the figure was approximately 50% - i.e., somewhat more than at the comparable noise level on Wehntaler Street (front); the percentages of disturbance of communication function reactions at comparable noise levels were also on the same order of magnitude. A relationship between the perceived noise annoyance and the general satisfaction with the quarter was also found in a Paris study [Ref. 2], the satisfaction with the quarter there being regarded as the variable influencing the extent of the annoyance due to noise which was perceived.

Table 10 shows classification of noise ranges which were established on the basis of results of the two Swiss studies [Ref. 9]. In accordance with this evaluation, the noise disturbances on the Wehntaler Street, the Winterthur Street, and on Long Street - with L_{50} values between 67 and 74 dB(A) during the day and between 48 and 67 dB(A) at night - can be designated very high; this is done on the basis of the "highly" of over 50%. The critical threshold for noise stresses which can be expected and in which the signs, interesting from the viewpoint of health, accompanying the noise disturbances increase sharply is clearly exceeded in these quarters. In these cases, clean-ups due to structural or traffic engineering measures - are indispensable. Even the case of 20-25% "highly" disturbed people - as in the case of Wehntaler Street (rear) - clean-up measures are desirable.

Table 10.

NOISE RANGES AND RESIDENTIAL QUALITY [Ref. 9].

L_{eq} in dB(A) during the day	Highly disturbed persons	Evaluation with respect to residential quality
up to 50	[illegible]	quiet residential zone
[illegible]	[illegible]	residential zone with moderate noise stress
[illegible]	[illegible]	high noise stress; measures desirable
over [illegible]	over [illegible]	very high noise stress; clean-up necessary

The criteria for evaluations for noise stresses which can be expected during the night are still deficient - primarily with respect to the suitable amount of noise as well. In any event, one must find that when there are more than 50% "highly" disturbed people at night as is the case with the residents in the streets which were studied, the amount expectable has been exceeded.

With respect to establishing guidelines and limiting values for planning or for clean-up measures, evaluations such as those established within the scope of this study on the basis of the disturbances due to noise and air pollution, should be used as bases for decisions. When this is done, if possible, the spatial requirements of city quarters should be taken into consideration. In addition, the question of further relevant parameters remains open; in addition to the noise level, further criteria such as the air pollution, the traffic loads, and the traffic composition, the type of construction, the location of the quarters should be taken into consideration as well.

Summary

The annoyance due to noise and air pollution to the residents of heavily frequented streets

The residents of different streets with varying traffic density and building density were questioned about annoyance due to traffic noise and air pollution. Frequency and extent of annoyance felt, effects of immissions on such living aspects as recreation, or communication, and also the reactions to the disturbance felt (such as closing windows and taking sleeping pills) were investigated. Noise levels as well as particulate matter and gaseous air pollutant concentrations were measured along the streets under investigation.

The evaluation of 1300 questionaires showed that reactions to noise were different in different quarters although noise levels were the same. In general, about 40 % of residents were heavily disturbed during daytime when the noise level Leq was around 65 dB(A); while for the same noise level at night about 55 % reported to be heavily disturbed. Strong correlations were also obtained between annoyance due to noise and that due to air pollution. The results show that annoyance felt is dependent not only on the measured noise levels and/or air pollution concentrations, but that there do exist interactions between the residential quarters and annoyance. These interactions should be considered while fixing the limits and standards

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