Annoyance due to industrial noise: perceptual assessment of legislation standard

S. Viollon[1], C. Marquis-Favre[2], C. Baumann

[1] *EDF R&D, Département Analyses Mécaniques et Acoustique, 1 avenue du Général de Gaulle, 92141 Clamart Cedex, France Email: stephanie.viollon@edf.fr*

[2] *LASH / DGCB URA CNRS 1652, ENTPE, 69518 Vaulx-en-Velin, Email: cathy.marquis@entpe.fr*

In France, the legislation standard for characterizing the noise impact of industrial sources is based on the concept of sound emergence [1]. This criterion is defined as the difference between the A-weighted equivalent sound pressure level of the ambient noise (source on) and the A-weighted equivalent sound pressure level of the residual background noise (source off). For industrial installations working 24 hours a day, the maximum legal values of this criterion are 5 dB(A) for the day period (7h-22h) and 3 dB(A) for the night period (22h-7h). For some noise exposure conditions, this criterion seems to be inadequate to assess noise annoyance as it is actually perceived by the residents. It is thus interesting to examine this criterion in a more-in-depth way.

As EDF group is engaged in a global policy of sustainable development and already applies an ISO14000 certification policy, the group wants to improve its knowledge and its control of the noise annoyance due to its installations. Its goal is to use noise impact criteria appropriate to its installations for a better assessment of noise annoyance perceived by the residents, and thus to enhance the environmental impact of its installations.

The task of seeking appropriate impact criteria for a better assessment of noise annoyance needs particular efforts as pointed out by many research works undertaken in the framework of annoyance due to transportation noise (Cf. review [2]). Berry and his colleagues have carried out interesting works on industrial noise by giving a review of various national standards [3], by evaluating the British standard and by proposing penalties for compressor and tonal fan noises using a traffic noise as baseline [4].

The objective of our current research work is to study how the sound emergence criterion is or is not adequate to assess the noise annoyance due to the different EDF installations. For this purpose, a sound perception test is carried out in laboratory conditions. Results are presented and discussed in particularly regarding the experimental parameters.

Experiment

During the sound perception test, subjects were asked to evaluate the perceived annoyance when listening to 4 recorded industrial sources noises, mixed with 3 recorded background noises, with the controlling of two values of the sound emergence +3dB(A) and +5dB(A).

Stimuli

Recordings have been realized with a stereophonic system (ORTF technique) linked to a DAT recorder. The 4 industrial noise sources under study were a cooling tower, a power plant turbine, a transformer with fans and a wind turbine. The three background noises corresponded to a quiet environment during night-time (L_{Aeq}=34.2dB(A), denoted later by "quiet"), a natural environment with birds songs (L_{Aeq}=43.1dB(A), denoted later by "natural") and a road traffic noise (L_{Aeq}=50dB(A), denoted later by "road").

From these recordings, 24 auditory stimuli have been obtained by mixing the 4 industrial sources noises to the 3 background noises with the control of the sound emergence +3dB(A) and +5dB(A). During the sound mixing process, each industrial noise was combined twice with each background noise for two emergence levels. Practically, the background noises were considered as reference signal without changing them. The recorded sound level of each industrial noise was thus modified in order to have the resulting sound level of the sound mixing *industrial source + background noise,* 3 dB(A) or 5 dB(A) greater than the sound level of the background noise under consideration.

All auditory stimuli were 15 seconds length.

Apparatus

The sound reproduction was carried out in a quiet listening room using two loudspeakers (JBL 6208) linked to a PC sound card (48kHz sampling rate, 16 bits sound quality). Subjects were faced to the PC graphical interface allowing the test answers to be automatically gathered.

Participants

Thirty-six subjects, all consisted of EDF staff, have taken part in the experiment. They were mainly constituted of men. Ages were from 25 and 50 years.

Procedure

Listeners were asked to evaluate how annoying the sounds were. Annoyance judgments were collected on a 7-point semantic differential scale ranging from (1) "a little annoying" to (7) "very annoying". The 24 auditory stimuli were dispatched up into 8 blocks of 3 sounds. The 8 blocks of sounds were presented to the listeners in a random order. Each block was constituted of mixed sounds resulting of one industrial noise combined with the three background noises for a given emergence level. Stimuli in each block were presented in random order to each listener. Subjects were asked to judge each stimulus regardless of their previous judgments. Subjects were trained with 7 auditory stimuli corresponding to all original industrial and background noises. The test was about 20 minutes long.

Results and discussion

Experimental factors

Three experimental factors were examined in this experiment. Their effects on the perceived annoyance were evaluated through an analysis of variance. The first experimental factor concerns the *type of industrial sources* and involves four levels (cooling tower, transformer and fans, power plant turbine, wind turbine). The second one consists of the three *background noises* (quiet, natural and road). Finally, both the *values of sound emergence* (+3dB(A) and +5dB(A)) constitute the third experimental factor.

Significant main effects of experimental factors

All the three experimental factors had a significant main effect on noise annoyance. This result is illustrated by the figure 1, showing the means of noise annoyance for each background noise (on x-axis are the four industrial sources, and on y-axis are the means of auditory ratings for each of both the sound emergence values).

There is no significant interaction between the experimental factors, pointing out that the main effects were on the whole independent between each others.

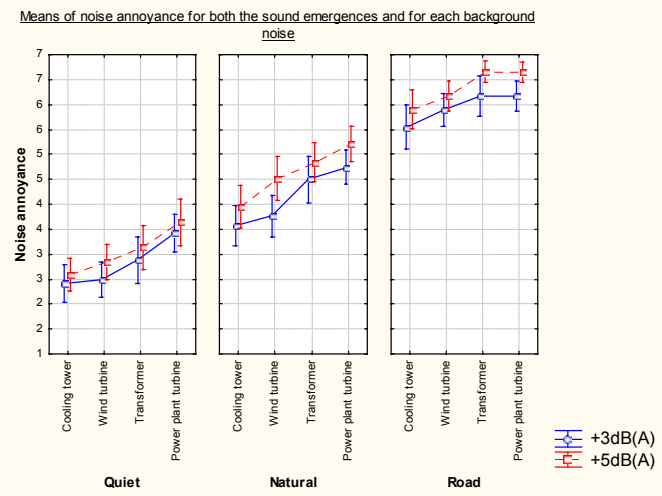

Figure 1: For each background noise, means of noise annoyance given for each sound emergence and all the industrial sources.

The background noises had a strong impact on the perceived annoyance [$F(2,68) = 254.3$; $p < 0.001$]. This result shows that our selection of very different types of background noises is successful.

On average for all background noises and industrial sources, subjects perceived a significant difference between both the values of sound emergence, +5dB(A) and +3dB(A) [$F(1,34) = 40.3$; $p < 0.001$], respectively corresponding to the day and night upper limits for French legislation.

Noise annoyance significantly varied along the type of industrial sources [$F(3,102) = 30.5$; $p < 0.001$]. On average, for a given background noise and a given sound emergence, noise annoyance depended on the industrial source : the power plant turbine was perceived more annoying than the transformer and fans, themselves more annoying than the wind turbine, and itself than the cooling tower.

As sound levels were arranged in our experiment to be the same for all sound sources, the spectral parameters or the connotation of the sound (e.g. in the case of the cooling tower) may explain the differences in noise annoyance between the various industrial sources. Actually, the power plant turbine noise presented a tonal component in high frequencies, the transformer and fans noise presented few tonal components in lower frequencies and finally, the cooling tower noise sounded like a waterfall. Thus, in our experiment, the French legal criterion, sound emergence, was not the best one to characterize the perceived impact of industrial installations.

Return on experience for future research work

In the aim of getting a more environmental approach of the matter, the sound recordings of industrial sources will be filtered, in order to simulate the spectral modification due to sound propagation between the recording point and the listening point.

Moreover, this experiment gives rise to a number of important questions for the future research work about noise annoyance due to industrial sources:

- which industrial sources should be recorded to constitute a representative set of the actual situation in France, and maybe in Europe?
- Should the recorded industrial sources be standing or intermittent sources? Should they work 24 hours a day?
- In our future experiments, should we set the sound level of the background noise and change the sound level of the industrial sources (like in this experiment) or make the inverse choice? Is it better not to choose any sound level references, neither background noises neither industrial sources?
- Which would be the optimal duration of sounds, to be judged by subjects and to simulate representative environmental situations?
- …

References

[1] French Standard, NFS31-010, *Caractérisation et mesurage des bruits de l'environnement*, december 1996.

[2] C. Marquis-Favre, E. Premat, D. Aubrée et M. Vallet *Noise and its effects – A review on qualitative aspects of sound. Part I: Notions and acoustic ratings*. Accepted for publication in Acta Acustica.

[3] N. D. Porter. *The assessment of industrial noise – A review of various national practices*. Proc. Euronoise, Vol. 14, Part 4, 1992.

[4] B.F. Berry and N.D. Porter. *The subjective and objective assessment of industrial noise*. Proc. Euronoise, Vol. 14, Part 4, 1992.