



## Health effects of aircraft noise near three French airports: results from the pilot epidemiological study of the DEBATS research program

A.S. Evrard<sup>a,b,c,\*</sup>, I. Khati<sup>a,b,c</sup>, P. Champelovier<sup>d</sup>, J. Lambert<sup>d</sup>, B. Laumon<sup>e</sup>

<sup>a</sup>Université de Lyon, F-69622, Lyon, France

<sup>b</sup>Université Lyon 1, UMRESTTE, F-69373 Lyon, France

<sup>c</sup>IFSTTAR, Transport, Health and Safety Department, UMRESTTE, F-69675 Bron, France

<sup>d</sup>IFSTTAR, Planning, Mobilities and Environment Department, Transport and Environment Laboratory (LTE), F-69675 Bron, France

<sup>e</sup>IFSTTAR, Transport, Health and Safety Department, Bron, France

---

### Abstract

DEBATS is an on-going research program (2011-2018) aiming to characterize the relations between the aircraft noise exposure and the health status of the French population living around three airports: Paris-Charles de Gaulle, Toulouse-Blagnac, and Lyon Saint-Exupéry. It includes:

- A longitudinal study whose objective is to follow-up 1,200 adult residents of these three airports during four years. Annoyance and health status are assessed by a face-to-face questionnaire performed at home. Blood-pressure and heart rate are also measured. Moreover, the participants are instructed to collect a sample of their salivary in order to determine their cortisol concentration.
- A sleep study aiming to characterize acute effects of aircraft noise on sleep quality using noise measurements. A pilot study was performed in 2011 in order to test and validate the protocol on 100 residents around Paris-Charles de Gaulle airport. The results of this pilot study are presented and discussed.

*Keywords:* Noise; Aircraft; Health; Residents.

---

### Résumé

DEBATS est un programme de recherche en cours (2011-2018) qui vise à caractériser les relations entre l'exposition au bruit des avions et l'état de santé de la population riveraine de trois aéroports français : Paris-Charles de Gaulle, Toulouse-Blagnac et Lyon Saint-Exupéry. Il inclut:

- Une étude longitudinale dont l'objectif est de suivre pendant quatre ans 1 200 riverains de ces trois aéroports. Un questionnaire administré en face à face au domicile des participants a permis de recueillir des informations sur la gêne de long terme et sur leur état de santé. Leur tension artérielle et leur rythme cardiaque sont également mesurés. Par ailleurs, il est demandé aux participants de prélever un échantillon de salive afin de déterminer sa concentration en cortisol.
- Une étude sommeil visant à caractériser les effets aigus du bruit des avions sur la qualité du sommeil en utilisant des mesures de l'exposition au bruit.

Une étude pilote a été menée en 2011 afin de tester et de valider le protocole sur 100 riverains de l'aéroport de Paris-Charles de Gaulle. Les résultats de cette étude pilote sont présentés et discutés.

*Mots-clé:* Bruit ; Avions ; Santé ; Riverains.

---

\* Corresponding author information. Tel.: +33 4 72 14 24 63.  
E-mail address: anne-sophie.evrard@ifsttar.fr



## 1. Introduction

Health issues related to airport noise pollutions became over the last years one of the key-questions which public policies want more to take into account. In 2004, the French “Conseil Supérieur d’Hygiène Publique” (CSHPF) delivered its recommendation related to the health protection of people exposed to airport noise: noise around airports is considered to be a public health problem, not only because of annoyance, but also because of sleep disturbances. CSHPF recommended that the knowledge of the French health situation resulting from aircraft noise exposure is improved by performing epidemiological studies. Further to this recommendation, the French Ministry of Health, in co-operation with the Airport Pollution Control Authority (Acnusa) asked the French National Institute for Transport and Safety Research (Inrets) (become the French Institute of Science and Technology for Transport, Development and Networks (Ifsttar) the first of January 2011), to perform an epidemiological research program named “Discussion sur les Effets du Bruit des Aéronefs Touchant la Santé” (DEBATS).

A national survey carried out in 2005 by Inrets shows that 6.6% of the French population is annoyed by aircraft noise (Lambert & Philipps-Bertin, 2009). Many surveys carried out both in France and abroad address aircraft noise annoyance (Vallet & Cohen, 2000; Bristow et al., 2004; Schreckenberg et al., 2009) or report adverse effects on sleep quality (Stansfeld et al., 2000; Hume et al., 2003; Franssen et al., 2004; Griefahn, et al., 2004; Lainey et al., 2004; Muzet, 2007; Basner et al., 2008). Much fewer consider at the same time the physiological effects of this noise exposure. The largest study to date is the HYENA study (Hypertension and Exposure to Noise near Airports). This study has evidenced an association between aircraft noise exposure and hypertension (Jarup et al., 2008) and suggests that exposure to aircraft noise increases morning saliva cortisol levels in women (Selander et al., 2009).

## 2. Objectives and methods

### 2.1. Objectives

DEBATS aims to characterize the relations between aircraft noise exposure and the health status of the French population living in the vicinity of airports, both physically and mentally but also in terms of annoyance. Some investigations have already been done or are ongoing near a lot of European airports but none has been carried out in France.

This project supports the development of public prevention policies of health risks. It will contribute to a wider and deeper knowledge of the French sanitary situation resulting from aircraft noise exposure. It will also grant to the request of people living near airports in France.

### 2.2. Methods

DEBATS is an on-going research program (2011-2018) involving adult residents around three French airports: Paris-Charles de Gaulle, Toulouse-Blagnac, and Lyon Saint-Exupéry (Cf. Figure 1).

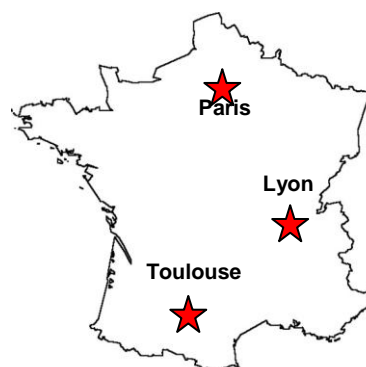


Figure 1. The three airports included in DEBATS



DEBATS includes:

- A longitudinal field study consisting in following-up approximately 1,200 of the above-mentioned airports residents during four years. At inclusion and two and four years later, annoyance and health status (in terms of sleep disturbances, cardiovascular diseases and anxiety and depressive disorders) will be assessed by a questionnaire performed by an interviewer at the home of the participants. Physiological variables like blood-pressure (BP), heart rate or salivary cortisol will also be considered within the frame of this study. One and three years after their inclusion in the study, a very simple questionnaire will be sent to the participants in order to keep in touch with them.
- A sleep study involving 100 individuals living in the vicinity of Paris-Charles de Gaulle airport. Its objective is to characterize specifically and in detail the acute effects of aircraft noise on sleep quality using accurate noise exposure measurements. Different types of measurements will be carried at the participants' homes. A first sonometer located in the participants' bedroom will record their noise exposure at night during a whole week. A second sonometer set up outside (at the bedroom façade) will allow us to identify the aircraft noise and to evaluate the impact of this noise in the participants' bedroom. Based on these measurements, different noise indicators will be set up regarding inside and outside of the dwelling: energetic indicators and noise events indicators. Moreover, the participants will be equipped with a dosimeter during one day in order to estimate their noise exposure outside their home. Sleep quality will also be assessed. Each participant will wear an actigraph (Actiwatch 4, Philips) on the non-dominant hand for seven nights, when the above-mentioned acoustic measurements are carried out. Simultaneously, they will complete a sleep diary. An actiwatch detects wrist movement and is useful for discriminating sleep from wake activity. Data from the actiwatch will be manually scored using the sleep-wake algorithm, and then, together with the sleep diary will make it possible to compute standard sleep variables per night and per participant.

The study area was defined on the basis of noise maps provided by the airports with the 'Integrated Noise Model' (INM). Residents living near France's largest airports can get noise insulation grants for their homes. To select which residents are eligible for this financial aid, a noise exposure map has been drawn up for each of these airports. These maps are based on estimated air traffic, applicable air traffic control procedures and infrastructures that will be in use in the year following the date of publication of the order approving the map. They consist of three areas (Cf. Figure 2).

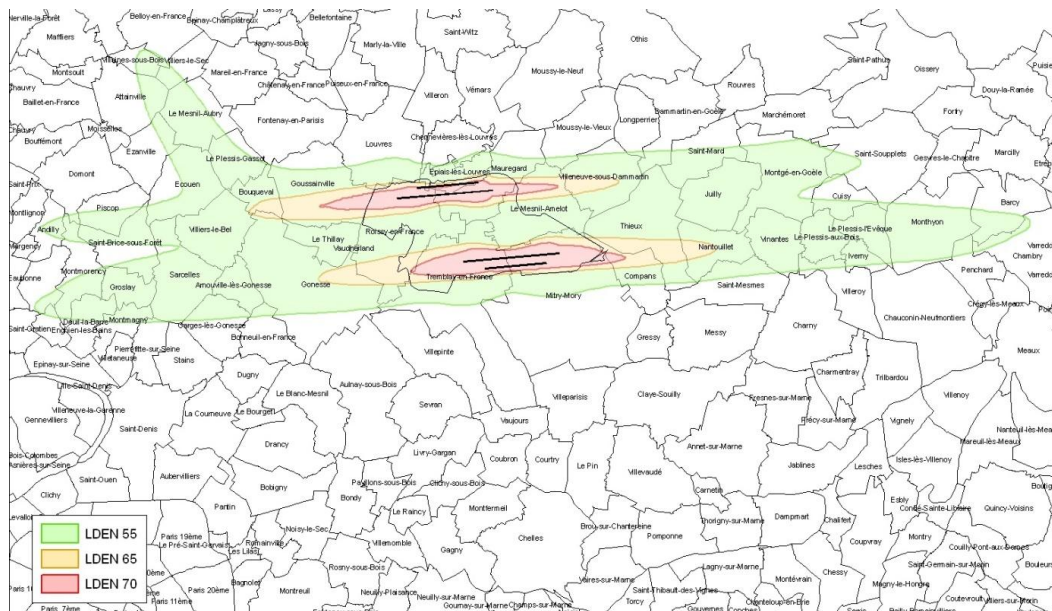


Figure 2. Paris-Charles de Gaulle airport noise exposure map

The first area indicates a very high level of noise pollution limited by the  $L_{den}$  70 index curve; the second one indicates a high level of noise pollution between the  $L_{den}$  70 and  $L_{den}$  65 index curves; and the last one indicates a moderate level of noise pollution between the  $L_{den}$  65 and  $L_{den}$  55 index curves. Within the frame of DEBATS, the French Civil Aviation Authority has assessed a fourth area which indicates a low level of noise pollution



between the  $L_{den}$  55 and  $L_{den}$  50 index curves. The study area has been divided into four zones in terms of  $L_{den}$ : <50 dB, 50-54 dB, 55-59 dB, and more than 60 dB. The participants have been selected in each of these noise exposure categories.

The protocol was validated by a scientific committee. A pilot study was performed in 2011 around Paris-Charles de Gaulle airport. Initially, it was planned to select one hundred participants (ten out of these participants for the sleep study): twenty-five in each of the four noise exposure categories. The objective did not consist in evidencing any scientific relationships, but in testing and validating the protocols of the longitudinal study and of the sleep study. Different stages of the protocols were tested: interviewers' recruitment, participants' selection (based on a phone numbers list), data collection, and data analyses. In particular, the pilot study aimed at:

- validating a recruitment cadency,
- estimating participation rates within the different noise exposure levels,
- characterizing from a demographic and a socioeconomic point of view the participants,
- testing the feasibility and technical methodology of physiological and acoustic measurements,
- and finally evaluating participants' agreement according to different devices.

In addition, this pilot study aimed at determining which energetic indicators and noise events indicators are more correlated with sleep quality. Therefore, a principal component analysis (PCA) was then conducted assuming that the sleep variables for one subject were independent.

### 3. Results

854 subjects were eligible for the pilot study in the study area (Cf. Figure 3).

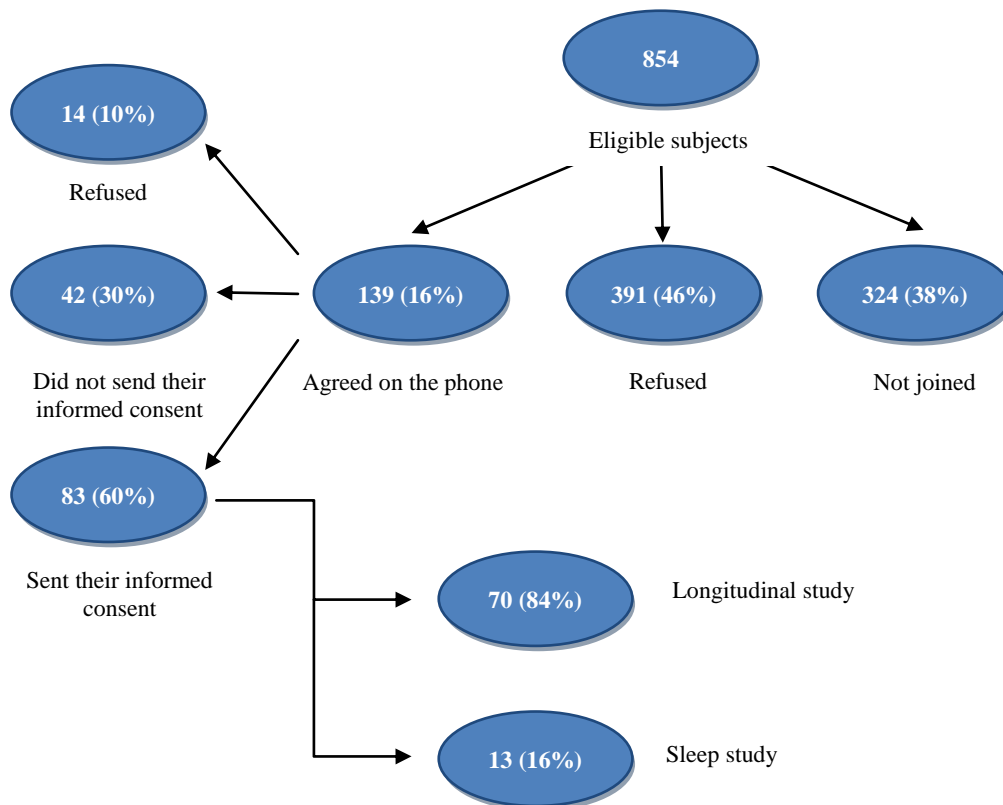


Figure 3. Participants' selection by phone

A total of 139 subjects (16%) agreed to participate when they were interviewed by phone, 391 refused (46%) and it was not possible to join 324 subjects (38%). Among those who agreed to participate, 83 (70 for the longitudinal study, 13 for the sleep study) sent their informed consent by mail or by email and finally participated in the pilot study (60%), 14 finally refused (10%) and 42 (30%) did not send their informed consent



despite several phone calls. The participation rate in the pilot study was finally equal to 10%. It was somewhat higher in the study area where exposure levels to aircraft noise is higher than 60 dB (16%), than in the other areas (<50 dB, 50-55 dB et 55-60 dB) where this rate was 12%, 9% and 10%, respectively.

Among the 391 subjects who refused to participate, 109 (28%) answered a very short questionnaire. The three main reasons for refusals were the following: “has no time to participate” (27%), “is not interested in participating” (14%), and “refuses that an interviewer comes to her/his home” (11%).

When interviewers went to participants’ home, two subjects finally refused to participate and four additional subjects were interviewed: 85 individuals were finally interviewed for the longitudinal study. Among them, 12 agreed to participate to the sleep study.

52% of participants in the longitudinal study were females (Cf. Table 1). The proportion of females was much higher in the sleep study (75%).

Table 1. Sociodemographic characteristics of the participants in the longitudinal study and in the sleep study

	Longitudinal study		Sleep study		Population of the study area
	n	%	n	%	%
<b>Sex</b>					
Female	44	52%	9	75%	52%
Male	41	48%	3	25%	48%
<b>Age</b>					
18-24 years	4	5%	1	8%	15%
25-34 years	8	9%	2	17%	17%
35-44 years	27	32%	5	42%	20%
44-54 years	22	26%	3	25%	18%
55-64 years	16	19%	1	8%	14%
65-74 years	4	5%			8%
≥ 75 years	4	5%			8%
<b>Marital status</b>					
Single	19	22%	3	25%	40%
Divorced	8	9%	1	8%	7%
Married	56	66%	8	67%	48%
Widowed	2	2%			6%
<b>Educational level</b>					
< French high-school certificate	26	31%	2	17%	61%
French high-school certificate	14	16%	3	25%	17%
> French high-school certificate	45	53%	7	58%	22%
<b>Housing tenure</b>					
Owner occupancy	65	76%	10	83%	41%
Tenancy	20	24%	2	17%	59%

The participants were slightly different from the population of the study area. The mean age of the participants in the longitudinal study was 49 years (standard deviation 13.4) against 42 years (standard deviation 10.8) for those included in the sleep study. People between 35 and 54 years of age were over-represented among the participants in the longitudinal study (58%) and in the sleep study (67%) compared with the population of the study area (38%). 66% of the participants in the longitudinal study were married (48% of the population of the study area). The education level of the participants in the longitudinal and in the sleep studies was higher than in the population of the study area: 53% (respectively 58%) had a certificate higher than the French high-school



certificate (22% of the population of the study area). 76% of the participants in the longitudinal study and 83% of those included in the sleep study owned their housing (41% of the population of the study area).

The distribution of the participants in the longitudinal study according to the four noise exposure categories was not homogeneous: most of the participants (70%) were living in an intermediate noise exposure area (50-54 dB or 55-59 dB), and very few participants (8%) were living in the most exposed area (more than 60 dB). In the sleep study, one participant was living in the <50 dB area, four participants in the 50-54 dB area, five in the 55-59 dB area and two in the more than 60 dB area.

The participants followed the protocol very well, especially when they participated in the sleep study. Blood pressure and heart rate measurements were available for all the participants. One participant finally refused to take a sample of saliva, and the determination of cortisol levels in saliva was not possible for two other participants. Acoustic measurements were available for 10 of the 12 participants due to technical problems of the sonometers and actimetric measurements were available for all the 12 participants. Finally, the database includes 62 nights for which noise indicators and sleep variables were simultaneously available. The PCA was conducted on these 62 nights. The strongest associations were evidenced between sleep quality and noise events indicators (NA37, NA40 and NA45) that were estimated inside, in the participants' bedroom.

#### **4. Discussion**

The originalities of the research program DEBATS are the following:

- The health effects study: while many surveys carried out in France address aircraft noise annoyance or report adverse effects on sleep quality, much fewer consider at the same time the physiological effects of this noise exposure.
- The follow-up of the participants over the time by the longitudinal study will allow us:
  - ✓ To study the health status evolution in terms of habituation, changes in the behaviours, and adaptation to the environment,
  - ✓ To highlight a latency time after which health effects have occurred,
  - ✓ And finally to characterize the residential mobility of people living around French airports.
- The search and the evaluation of a link between the psychosociological effects of aircraft noise (annoyance for example) on one hand and the physiopathological effects on the other hand.
- The use of noise event indicators to characterize aircraft noise exposure: most of the epidemiological studies on this topic used energetic indicators.
- Acoustic measurements inside the dwellings will make it possible to take into account the building outdoor insulation and the opening/closing practice of the windows unlike French and European regulations as well as epidemiological studies which are based on noise exposure at the façade of the buildings.
- Actimetric measurements very seldom used in epidemiological studies will make it possible to assess the objective sleep quality of the participants.

The participation rate in the pilot study of the research program DEBATS was generally a little lower than those observed in previous epidemiological studies carried out in France. This result could be explained by the fact that because people receive more and more phone calls from telemarketing companies, they often hang up before the interviewer has the opportunity to present the study. Moreover, most of the people living in the vicinity of Paris spend a lot of time commuting and therefore has no time to participate to studies.

The participation rate was somewhat higher when aircraft noise exposure was the highest. This result could be explained by the fact that subjects living in the most exposed area were more often called back when they did not answer than subjects living in other areas.

Very few participants (8%) were living in the most exposed area (more than 60 dB). Not enough phone numbers were selected at random in this noise exposure category to obtain as many participants as in the other categories. In the real study, it will be necessary to select more participants exposed to noise levels higher than 60 dB. Therefore it is planned to follow 300 individuals in each of the four noise exposure categories.





The participants in the pilot study were slightly different from the population of the study area: there were more educated and people between 35 and 54 years of age were over-represented among the participants. This selection bias is very similar to those observed in other epidemiological studies carried out in France.

Subjects easily agreed to participate in the sleep study. Participants followed the protocol very well, especially when they participated in this sleep study.

Actigraphy constitutes a reasonably reliable tool in sleep research for producing objective measurements of sleep/wake, but it is not enough accurate for identifying arousals. Therefore, in addition, in the real sleep study, the subjects will wear a heart rate monitor during one night, provided these measurements are validated on some subjects because they were not tested before in terms of technical feasibility and subjects' acceptability. The actimetric measurements and heart rate monitoring will make it possible to characterize arousals more precisely and to investigate a link between aircraft noise and sleep quality.

The PCA is a descriptive method whose objective was to describe and graphically represent correlations between the calculated noise indicators and the sleep variables. But it is not an end in itself. It allowed us to formulate hypotheses that will be more precisely investigated with statistical models in the real sleep study.

The strongest associations were evidenced between sleep quality and noise events indicators that were estimated inside, in the participants' bedroom. The energetic indicators currently used by the European regulations and recommendations do not seem to be sufficient when sleep quality is considered and need to be completed. However, these results are only based on a dozen of participants living in the vicinity of Paris-Charles de Gaulle airport and need to be replicated on more individuals. That is the reason why 100 participants will be included in the real sleep study, twenty-five in each of the four noise exposure categories.

### Acknowledgements

The Airport Pollution Control Authority (Acnusa) asked the French Institute of Science and Technology for Transport, Development and Networks (Ifsttar) for implementing DEBATS. The present authors would like to thank them for their confidence.

This research program is supported by funding from the French Ministry of Health, the French Civil Aviation Authority, and the French Ministry of Environment. The pilot study was supported by the French Ministry of Health and the French Agency for Food, Environmental and Occupational Health & Safety (Anses). The present authors would like to thank them for their kind assistance.

### References

- Basner M., Glatz C., Griefahn B., Penzel T., Samel A. (2008). Aircraft noise: effects on macro- and micro-structure of sleep, *Sleep Medicine*, 9(4), 382-387.
- Bristow A., Batley R., Wardman M., Heaver C. and Plachinski E. (2004). A comparative analysis of annoyance from aircraft noise at three European airports. In *European Transport Conference Proceedings*.
- Franssen E.A., van Wiechen C.M., Nagelkerke N.J. and Lebret E. (2004). Aircraft noise around a large international airport and its impact on general health and medication use, *Occupational and Environmental Medicine*, 61(5), 405-413.
- Griefahn B., Scheuch K., Jansen G. and Spreng M. (2004). Protection goals for residents in the vicinity of civil airports, *Noise and Health*, 6, 51-62.
- Hume K., Gregg M., Thomas C. and Terranova D. (2003). Complaints caused by aircraft operations: an assessment of annoyance by noise level and time of day, *Journal of Air Transport Management*, 9(3), 153-160.
- Jarup L., Babisch W., Houthuijs D., Pershagen G., Katsouyanni K., Cadum E., Dudley M.L., Savigny P., Seiffert L., Swart W., Breugelmans O., Bluhm G., Selander J., Haralabidis A., Dimakopoulou K., Sourtzi P., Velonakis M. and Vigna-Taglianti F. (2008). Hypertension and exposure to noise near airports: the HYENA study, *Environmental Health Perspectives*, 116(3), 329-333.



Lainey E., Nerome S., Enjalbert J.P., Bouee S. and Deschaseaux-Voinet C. (2004). INSOMNIA: Impact des Nuisances SONores (Maladies et INsomnie) à proximité des Aéroports, Hôpital Européen Georges Pompidou (CEMKA-EVAL).

Lambert J. and Philipps-Bertin C. (2009). Les nuisances environnementales des transports : résultats d'une enquête nationale, *Rapport INRETS (278)*, INRETS.

Muzet A. (2007). Environmental noise, sleep and health, *Sleep Medicine Reviews*, 11(2), 135-142.

Schreckenber D., Heudorf U., Eikmann T., Herr C., zurNieden A. and Meis M. (2009). Aircraft noise and health of residents living in the vicinity of Frankfurt Airport. In *Proceedings of Euronoise*, Edinburgh, Scotland.

Selander J., Bluhm G., Theorell T., Pershagen G., Babisch W., Seiffert I., Houthuijs D., Breugelmans O., Vignataglianti F., Antoniotti M.C., Velonakis E., Davou E., Dudley M.L. and Jarup L. (2009). Saliva cortisol and exposure to aircraft noise in six European countries, *Environmental Health Perspectives*, 117(11), 1713-1717.

Stansfeld S., Haines M., and Brown B. (2000). Noise and health in the urban environment, *Reviews on Environmental Health*, 15(1-2), 43-82.

Vallet M. and Cohen J.M. (2000). Étude épidémiologique des troubles anxio-dépressifs autour des aéroports, *Rapport LTE (2008)*, INRETS.