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2013 | INNSBRUCK | AUSTRIA
15.-18. SEPTEMBER 2013
NOISE CONTROL FOR QUALITY OF LIFE

Noise generated by the Paris ring-road: state of knowledge and issues

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ABSTRACT

The Paris ring-road carries one quarter of all Paris traffic and represents an important link between Paris and the surrounding towns. With over 100,000 people living along its 35 km, the ring-road is also one of the noisiest roads in Paris according to the noise maps produced by the city of Paris within the framework of the implementation of European directive 2002/49/EC.

In order to better understand the reality of these nuisances and to complete the strategic maps of noise, Bruitparif carried out a large measurement campaign over one month in 2009. This campaign allowed the description of variations in noise over time, the improvement of knowledge on the relationship between noise and traffic conditions, and a focus on sudden noise events (car horns, and particularly noisy two-wheeled motor vehicles). Further studies were conducted in 2010/2011 in order to quantify the population exposed to noise above the threshold values along the ring-road and to study the potential impact of some solutions. The monitoring went on with the setting up of permanent measurement stations to follow the evolution of noise levels over time.

The main results of these studies will be presented and discussed.

1. STRATEGIC NOISE MAPS

Within the framework of the implementation of the European directive 2002/49/EC, the city of Paris produced and published noise maps on its website on 30th June 2007 (see Figure 1). These maps were created by modeling with average traffic and topographic data (taking into account relief, buildings, screens, etc.) and they provide average annual noise levels, through the use of two indicators that have been harmonized at European level.

- The Lden indicator, which represents average noise levels during the day, taking into account a weighting of +5dB (A) for evening levels (between 6pm and 10 pm) and +10 dB (A) for night levels so as to take into account the increased sensitivity to noise of inhabitants at these periods.
- The Ln indicator, which represents average noise levels over night-time (10 pm to 6 am).

These maps enable us to rapidly identify areas with serious issues in terms of noise. This is obviously the case of the ring-road, which generates levels that can reach or exceed 80 dB(A) according to the Lden indicat or, and 75 dB(A) according to the Ln indicator.

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Moreover, these maps allow us to estimate the distribution of Parisians according to their potential exposure to noise (assessed according to the most exposed façade of their homes). Threshold values have been issued by France: 68 dB(A) for the Lden indicator and 62 dB(A) for the Ln indicator. The use of these maps thus allows us to estimate the proportion of inhabitants exposed beyond these threshold values. In the case of Paris, this proportion rises to 25 % for the Lden indicator, and to 16 % for the Ln indicator.

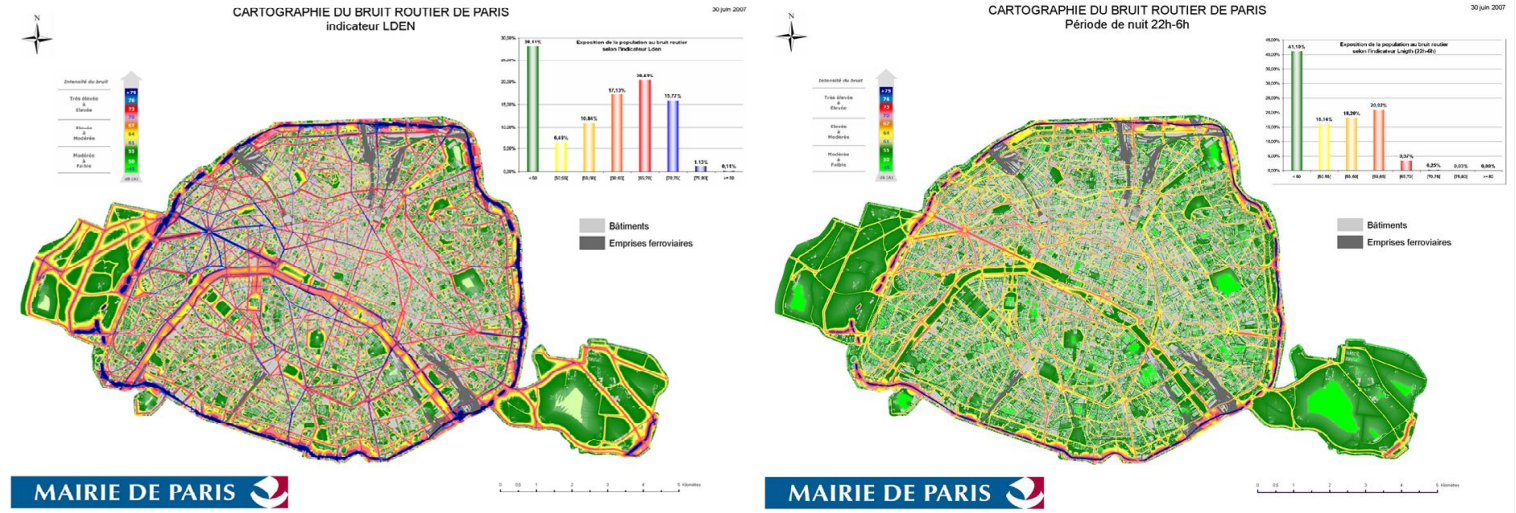

Figure 1: Mapping of Paris traffic noise : Lden indicator (left) and Ln indicator (right)

(source: noise maps published on 30th June 2007 by the city of Paris).

2. THE NOISE MEASUREMENT CAMPAIGN

Strategic noise maps offer a spatial image of the sound environment around the ring-road, but they do not describe variations in noise over time, or sudden noise events (car horns, and particularly noisy two-wheeled motor vehicles). Such aspects are, however, at the heart of residents' concerns, and raise manifold questions:

- What are the noisiest or the quietest times?
- What relationship is there between noise, traffic conditions (flows, speed, saturation, traffic composition) and the lay-out of the place (ring-road embanked or entrenched in relation to the lodgings, presence of anti-noise screens, impact of side lanes, etc.).
- What are the noise dynamics and what is the contribution of sudden noise events (horns, sirens, two-wheeled motor vehicles)?

In order to address such issues and to complete the strategic noise maps made by the city of Paris and the 21 surrounding towns in the Haut-de-Seine, Seine-Saint-Denis and Val-de-Marne departments, Bruitparif launched a large measurement campaign around the ring-road. At the heart of the system, 8 fixed noise measurement stations recorded traffic-generated noise near residential housing on each side of the ring-road for 24 hours a day, second by second. In order to complete this system, a laboratory vehicle, equipped with innovative technologies and energetically self-sufficient thanks to its onboard solar panels, collected about 50 one-hour samples, or one sample every 700 meters. The idea was to have a homogenous spatial distribution of measurement points around the ring-road and to have a permanent station at hand on the sections located between the large highway interchanges.

Different lessons were learned from this measurement campaign.

2.1 Very high noise levels

The sound levels around the ring-road are extremely high and regularly exceed the regulatory limits by night and by day when no noise control has been set up. Thus, concerning the Lden indicator (see Figure 2), one can see that sites without noise control all present values well in excess of regulatory French threshold value (between 7.5 and 10.9 dB(A) over 68 dB(A)). And this is also the case for the Ln indicator. Sites without sound screens all have values well above the night-time French threshold limit of 62 dB(A). Two out of three sites fitted with a sound screen are slightly under these thresholds.

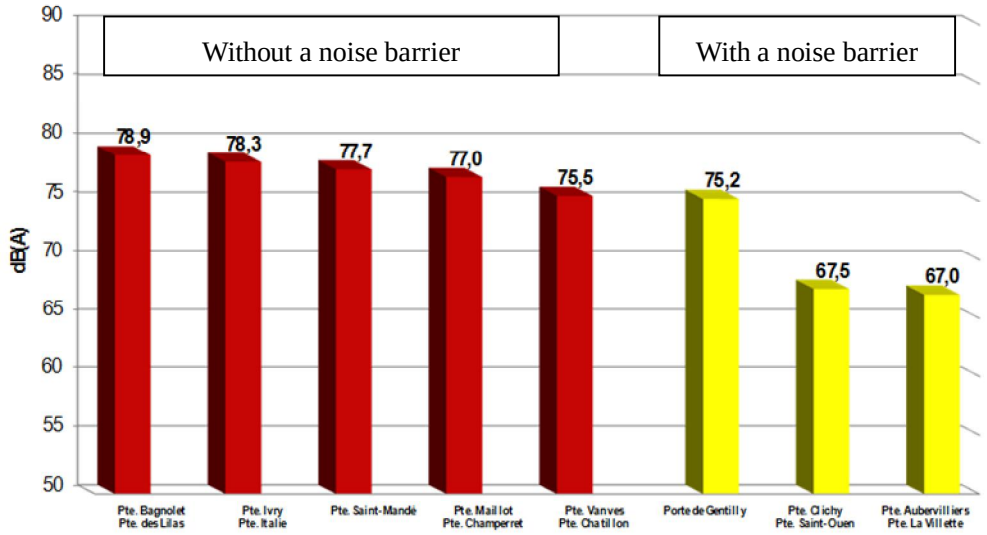

Figure 2: Average daily noise levels Lden Indicator for the 8 fixed stations.

2.2 Results that back up and complete the values drawn from the modeling

The results of the measures have been compared with the values of the noise map created by modeling by the city of Paris within the framework of the implementation of the European directive 2002/49/EC.

On the whole, for most of the sites involved, the measurements results match the digital simulation. Thus, 73.5 % and 75.5% respectively of the sites offer deviations below or equal to 5 dB(A). The average deviations between the map results and the measurements are relatively low: +1.4 dB(A) for the Lden indicator and +0.8 dB(A) for the Ln indicator, which proves that the map matches the measurements on the whole, with a tendency of the modeling to overestimate values: in 82% of the sites studied for the Lden indicator and 69% for the Ln indicator, the values drawn from the strategic map of environmental noise are higher than the values measured on site.

Sites with a deviation above 5 dB(A) have been further analyzed. For the most part, the deviations result from imperfectly taking into account some acoustic protections in the digital simulation model.

2.3 Highly pervasive noise

The sound of road traffic for people that live along the ring-road is very pervasive. Measurements have shown high values from as early as 5 in the morning and until midnight. During the night, the noise decreases slightly but nonetheless remains high. The levels recorded between 2 am and 4 am are only 6 dB(A) lower on average compared to the noisiest period (between 6 and 7 am) (see Figure 3).

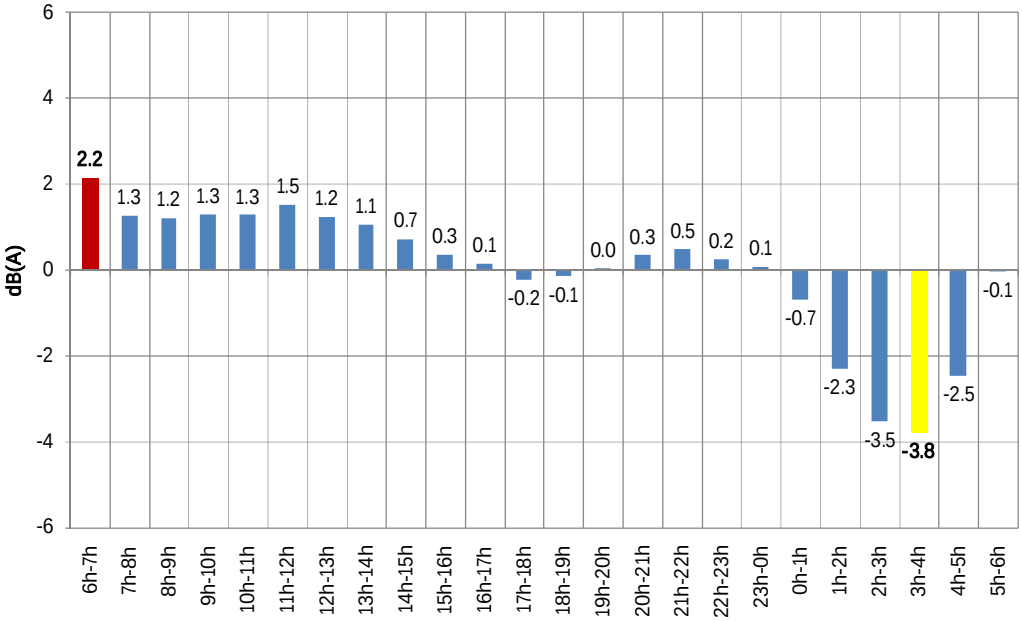

Figure 3: Hourly variations in noise levels from the daily average for week-days.

There are also few variations in relation to the day of the week. Night levels can even be higher during the week-end (see Figure 4). The conclusion is that for residents whose façades are exposed to the ring-road, there is no break: not at night or at the week-end, or even during the school holidays (during which the average levels recorded were only 1 dB(A) lower).

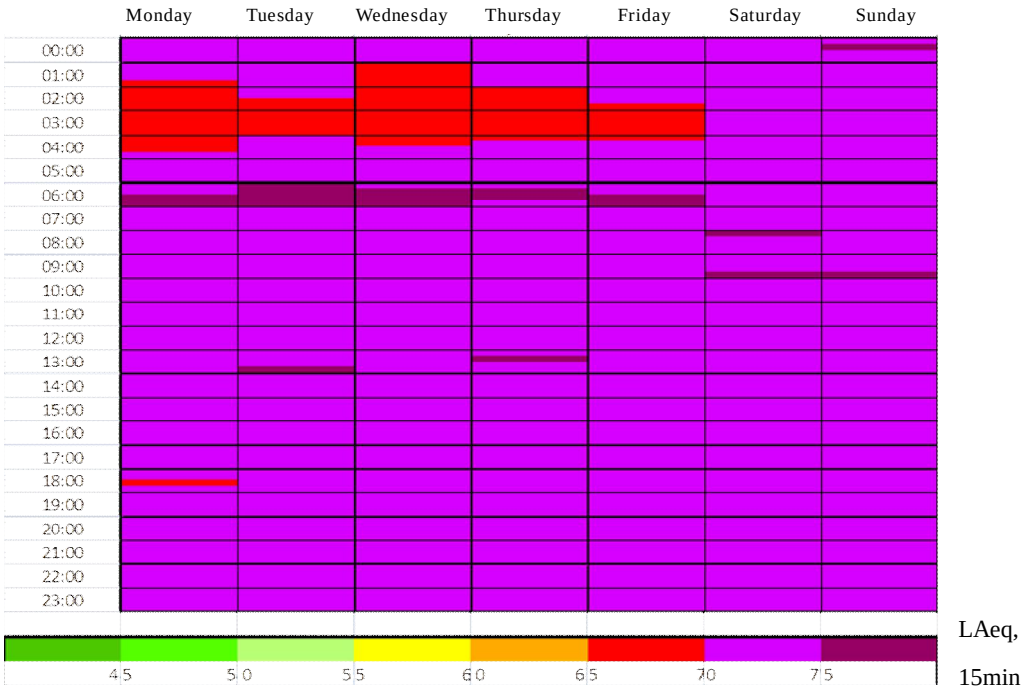

Figure 4: Variations in sound levels (LAeq by 15 minutes intervals) during the week on the site between Porte de Bagnolet and Porte des Lilas.

2.4 The impact of noise control devices

A reassuring element is that the study demonstrates the effectiveness of noise barrier set up along the ring-road. Indeed, on average, the screens reduce noise levels by around 7 dB(A). This improvement is less than the theoretical decrease (see Figure 5), but is nevertheless quite significant when you consider that a 10 dB(A) decrease represents a halving of the hearing sensation (the impression of noise feels half as strong). This decrease in noise levels allows, in some cases, compliance with regulatory threshold values. This result should, however, be qualified, as noise control devices are mainly effective for lodgings on the lowest floors of buildings.

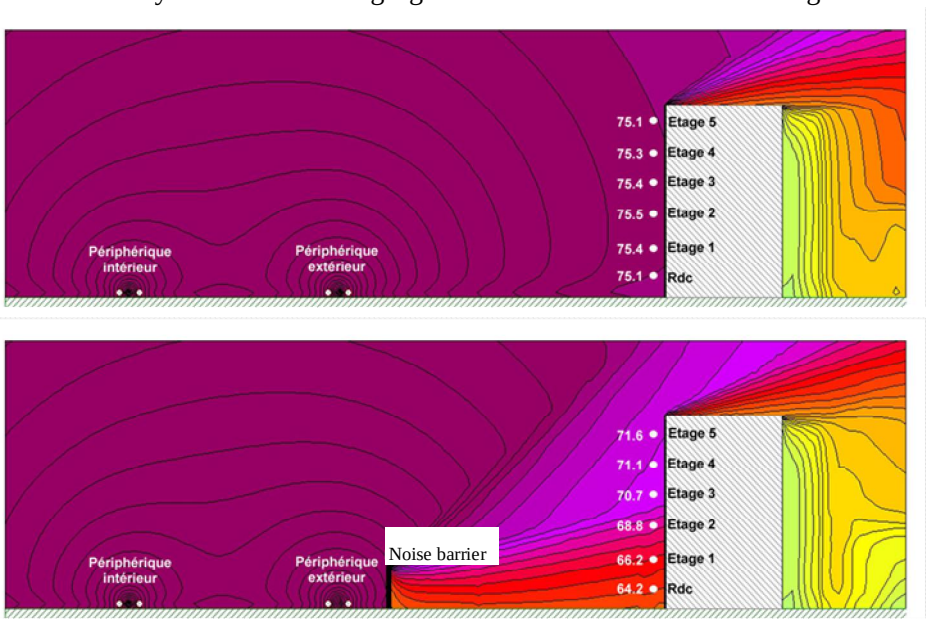

Figure 5: Theoretical decrease of noise levels on a building after setting up an anti-noise wall.

2.5 Better knowledge on the relationship between noise and traffic conditions

As a first approximation, with all other parameters remaining constant (traffic conditions, vehicles in use, site configuration), the level of noise near transport infrastructure varies according to the flow Q (v/h) and speed V (km/h) of vehicles within this formula:

$\Delta Lp = 10 \log(Q / Qref) + 20 \log(V / Vref)$ if $V \geq 50$ km/h (source: NFS standard 31-085).

At constant speed, a doubling of the flow therefore theoretically causes a 3 dB(A) increase in the noise level. At constant flow, dividing the speed by two reduces noise by about 6 dB(A).

The measurement campaign has allowed us to document and to understand in detail the relationships between noise and traffic conditions and in particular to highlight the importance of the influence of traffic speed.

Thus, this analysis brings to light the fact that the noisiest situations are traffic configurations with simultaneously high flows and high speed and that noise tends to decrease in situations of saturation (which is in accordance with theory).

Furthermore, the analysis shows that the period between 5 and 7 am is particularly noisy. This is partly due to the high speed of vehicles at such a time and also probably due to a higher proportion of lorries and freight vehicles during this period compared with the rest of the day.

The Figure 6 therefore allows us to understand the hourly noise levels observed at the station located at Porte de Saint Mandé, depending on traffic conditions. This three-dimensional representation allows us to visualize the whole set of traffic conditions observed during the month of measurement and the associated noise levels.

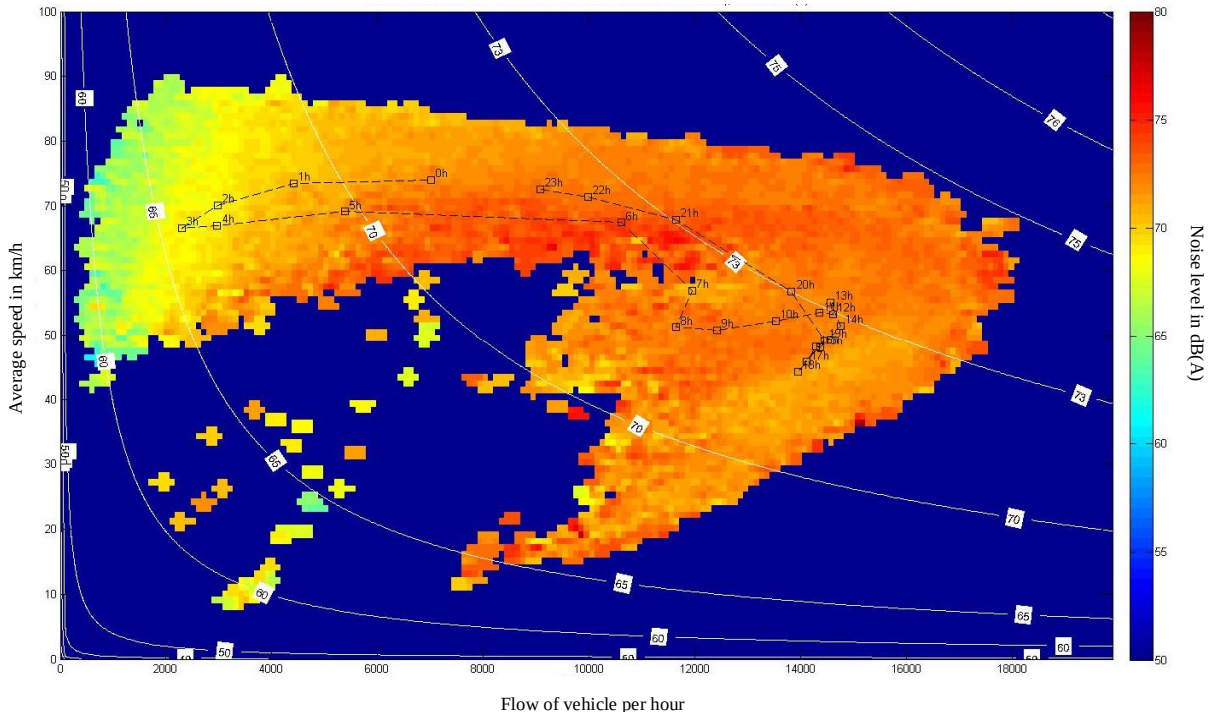

Figure 6: Simultaneous view of flow/speed/noise levels (all days)
for the measurement site at Porte de Saint Mandé.

The graphs presented in Figure 7 illustrate the noise levels generated by the three most common traffic situations occurring on the ring-road:

- Free-flowing traffic in the middle of the night: little vehicle traffic (around 1,500 vehicles per hour) but high average speed (78 km/h: very close to the speed limit)
- Saturated traffic during peak morning hours: high traffic (11,000 vehicles per hour) and low average speed due to the congestion (around 22 km/h)
- Dense and fluid traffic conditions in the middle of the day: high traffic (14,000 vehicles per hour) and relatively high average speed (around 63 km/h due to relatively fluid traffic conditions)

These graphs were produced using the results from the measurement site located between Porte de Bagnolet and Porte des Lilas.

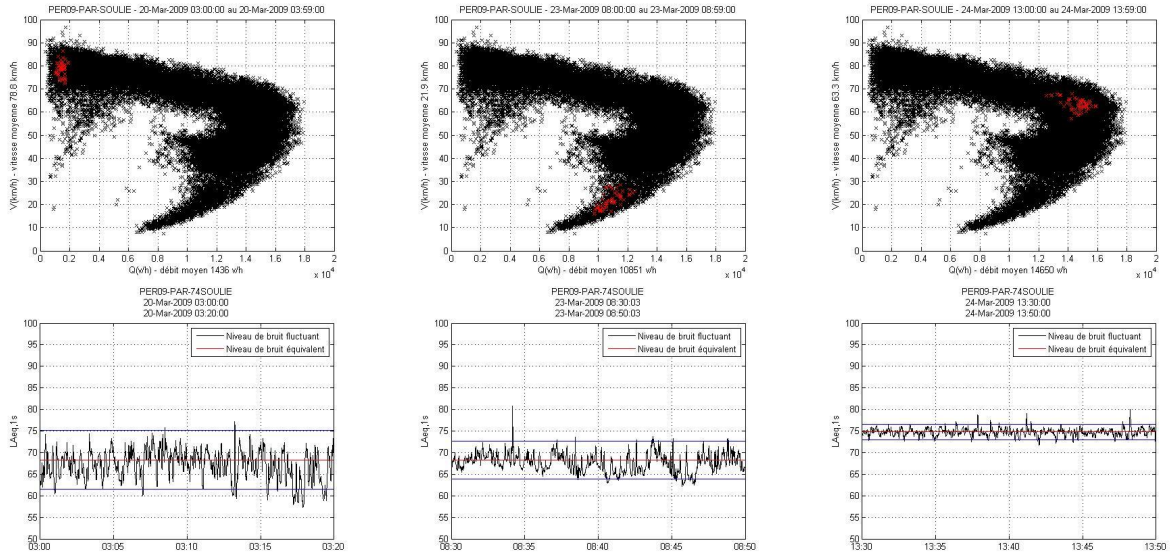

Figure 7: Noise levels and traffic conditions for 3 common situations observed on the ring-road.

The average noise level observed in conditions of dense and free-flowing traffic at the beginning of the afternoon exceeds the levels observed for the two other periods by about 6.5 dB(A). At peak hours, in conditions of saturated traffic, the average noise is almost equal to the level measured in the least noisy situation, in the middle of the night, while the number of vehicles is nearly eight times higher. The noise reduction caused by lesser use of the ring-road is compensated by an increase of the noise level due to the increased speed.

2.6 Quantification of noise peak events

The study has allowed us to precisely qualify and quantify the events that significantly exceed (by over 10 dB(A) the background traffic noise, which is already quite high). According to the configurations observed around the eight fixed stations, between 100 and 1,600 noise emerging events (sudden noise events that significantly exceed the background noise levels) were recorded daily. Such noise emerging events can be related to the passage of particularly noisy vehicles on the ring-road, and also to the passage of isolated vehicles on the service lanes between the ring-road and the first line of residential buildings. Significant noise emerging events (reaching up to 25 dB(A)) have been observed in the middle of the night. These are mainly related to the passage of two-wheeled motor vehicles, which are either particularly noisy or driving at an excessive speed. The intensity of such events and their occurrence at night make them an important source of nuisance and sleep disorders for residents. As for sirens, they were mainly identified during the day or in the evening when traffic is dense or saturated.

2.7 Not necessarily any time correlation between noise and air pollution

For this campaign, Bruitparif teams have been able to compare measurement data with data collected by Airparif (the air quality organism in charge of monitoring air quality on the Ile-de-France region), during previous studies for two sites. The results show that although road traffic is the main cause of both types of pollution, there is no time correlation between the two nuisances. Indeed, air quality is most affected during peak hours (for particles and nitrogen oxides) while noise levels tend to be higher when there is less traffic but a higher speed (as is the case during the time slots between 6 and 7 am, 11 am and 12 pm, and 8 pm and 11 pm). The noisiest times of day, therefore do not necessarily correspond to peak traffic hours, nor to the times of heaviest air pollution (see Figure 8).

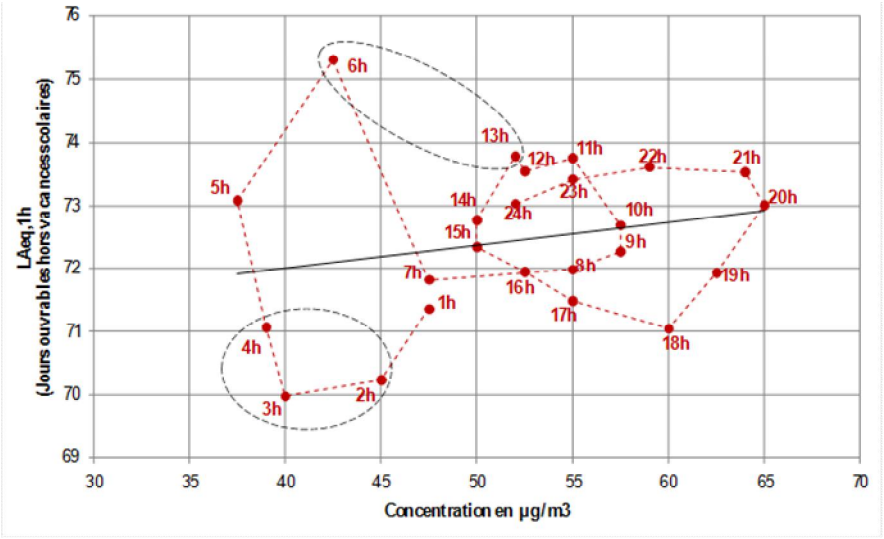

Figure 8: Couples hourly nitrogen dioxide concentrations/noise levels at Porte de Bagnolet.

2.8 Recommendations

All these elements have allowed us to issue a number of recommendations to the main stakeholders to fight even more effectively against the noise nuisances generated by the ring-road.

Besides the multiplication of noise protections and the improvement of the façade insulation of buildings adjacent to the ring-road, other means can be considered, in particular by reducing noise at its source.

To ensure the peace of residents, the priority is to decrease night-time noise. This could be done by reducing the speed limit or by encouraging drivers not to exceed 50 km/h at night. Special care should be devoted to the period between 5 and 7 in the morning, when noise levels are particularly high. It would be worth making a further study coupling noise measurement and traffic composition over this period so as to better understand the contribution of freight vehicles and lorries in the noise levels observed.

The use of the latest generation of low-noise road surfaces would allow a reduction of few decibels, especially when traffic speed is relatively high (a theoretical gain of 5 dB(A) for a speed of 70 km/h).

During new planning operations or the renovation of some areas, special attention should be paid not to increasing the number of homes exposed to the noise of the ring-road, by favouring the construction of buildings for commercial or work purposes in the first line, which can work as screens for the residential buildings on the second line.

Prevention and awareness-raising actions should also be reinforced in order to promote less noisy behaviour on the ring-road. To that effect, setting up signs displaying noise levels and prevention messages might be a relevant solution to experiment. Engaging the users of the ring-road, especially two-wheeled motor vehicle drivers that are particularly noisy or driving at excessive speed, which is one of the main causes of noise peaks during the night, could be a worthwhile objective.

3. FURTHER STUDIES CONDUCTED BY BRUITPARIF IN 2010-2011

In the wake of the study carried out in 2009, and so as to bring to light complementary elements within the framework of the preparation of the environmental noise action plans for Paris, as well as neighbouring towns, Bruitparif has quantified the population exposed to noise above the threshold values along the ring-road and has studied the potential impact of some solutions that could be considered.

3.1 Estimation of the population exposed to the noise of the ring-road

From the road noise map made by the City of Paris and published on 30th June 2007 in application of European directive 2002/49/EC, we have been able to estimate the number of people that live near the ring-road and are potentially exposed to sound levels exceeding the threshold values made by France for traffic noise (68 dB(A) for the Lden indicator and 62 dB(A) for the Ln indicator).

To do this, three steps were necessary:

- A selection of the buildings within a buffer zone of 150 m on each side of the ring-road, which are mainly impacted by the noise generated by the ring-road.
- A selection of exclusively residential buildings and an estimation of the population in these buildings thanks to a population layer provided by the IAU Ile de France (regional institute dealing with urban and regional planning).
- An estimation of the potential level of exposure to noise for the population of each building from the level of the most exposed façade.

The results have shown that about 61,000 people are mainly impacted by the noise of the ring-road within the 150 m buffer zone on each side of the ring-road. Among them, 41,000 people (68%) might be potentially exposed to levels that exceed the threshold value for noise relative to the weighted average daily indicator (Lden > 68 dB(A)).

37,300 residents of the ring-road are likely to suffer also from nightly noise nuisance exceeding the relevant threshold value (Ln > 62 dB(A)).

One can also see that the levels of exposure to noise can be well above the threshold values: indeed, they can reach values exceeding the threshold values by up to 15 dB(A). It should be noted that over 5,000 people are potentially exposed to noise levels exceeding the Lden and Ln threshold values by at least 10 dB(A) (that is to say, noise levels perceived by the human ear as being at least twice as high as the threshold values).

3.2 Potential impact of noise reduction actions in terms of exposed people

Bruitparif has been able to quantify the potential impact of actions that could be considered in order to decrease the noise levels on the ring-road in terms of a decrease of the number of people exposed beyond threshold values (see results in Figures 9 & 10).

In order to ensure the peace of the residents along the ring-road, the priority should be to counter nightly noise. To that effect, a reduction of the legal speed limit from 80 km/h to 50 km/h would be likely to reduce the real traffic speed by 20 to 25 km/h, which would theoretically translate into a decrease in night-time noise levels by about 3 dB(A). This measure would reduce the number of people exposed to night-time noise levels exceeding the threshold value by about 26%. On the other hand, this measure would only reduce the number of people exposed to daytime noise levels exceeding the limit value for the Lden indicator by about 4 %.

Other complementary actions must therefore be considered to reduce noise at its source.

One possible measure could be to opt for low-noise road surfaces that provide better acoustic characteristics than the ones currently used on the ring-road. For a speed limit of around 50 km/h, by changing the road surface materials we could hope for a noise reduction of about 3 dB(A) according to the review of knowledge on this topic carried out by Bruitparif in 2011. Life-scale experiments will nevertheless have to be implemented so as to approve the technical feasibility of the laying and durability of such road surface materials on a road as busy as the ring-road, as well as the actual acoustic gains obtained. The advantage of this type of solution is that the benefit will be permanent, by day as well as by night. Therefore, if such an action was carried out in conjunction with a lowering of the speed limit at night, the number of people that suffer noise levels in excess of the threshold value at night would decrease by about 59 % compared to the current situation. As regards the number of people that suffer noise levels in excess of the threshold value for the Lden indicator, the decrease would be closer to 27 %.

Another way to significantly decrease noise at its source would be to reduce the proportion of lorries. It should be noticed that, from an acoustic point of view, the average lorry is equivalent to around 7 individual vehicles at a speed of 80 km/h speed and to 10 individual vehicles at a speed of 50 km/h. Dividing the number of lorries and freight vehicles circulating on the ring-road by half would theoretically translate into a decrease in noise of 1.5 dB(A) on average, and 2 dB(A) at the end of the night when the proportion of lorries and freight vehicles seems to be particularly high. If such a measure was added to the two previous ones (reduced speed limit at night and a change in road surface material), the number of people above the threshold value would fall by about 69 % (around two thirds) compared to the current situation. As regards the number of people over the threshold value for the Lden indicator, the decrease would be around 44 %.

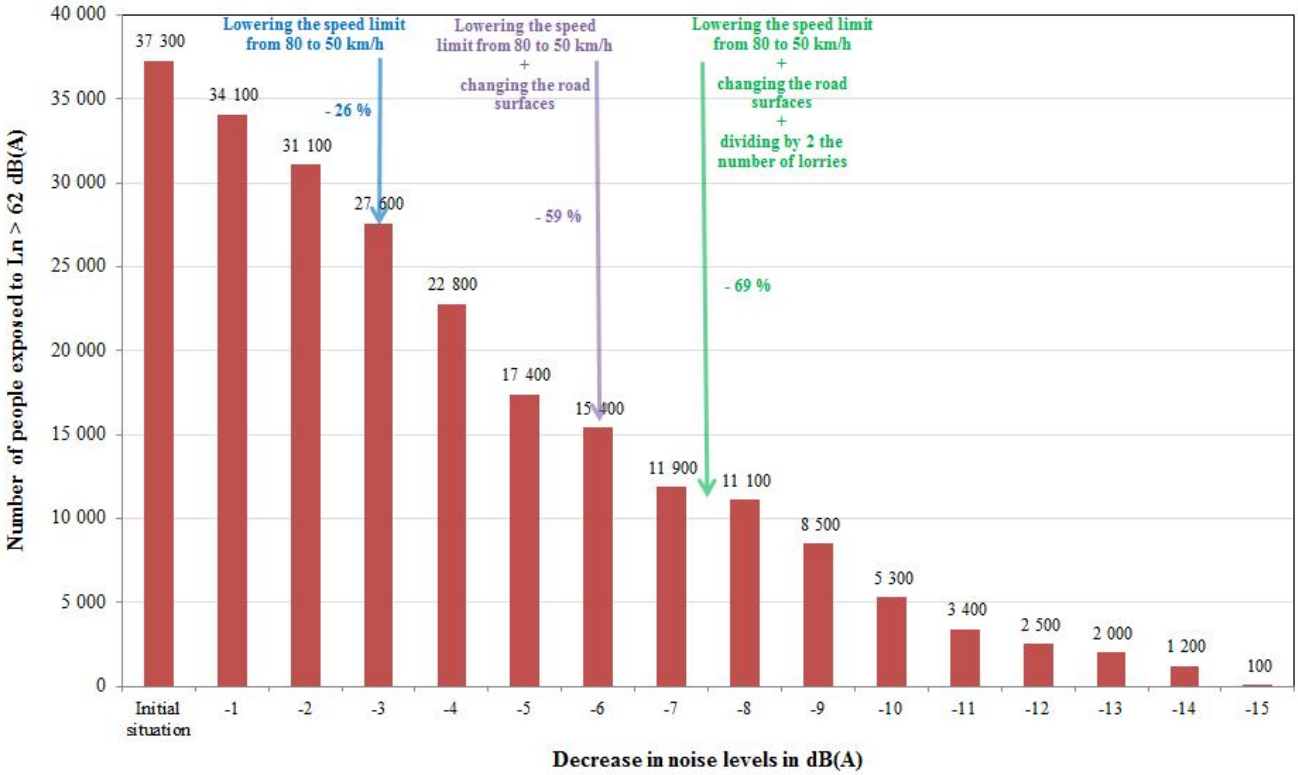

Figure 9: Estimation of the impact of actions against noise in terms of diminution of the number of people exposed over the threshold value for Ln indicator (62 dB(A))

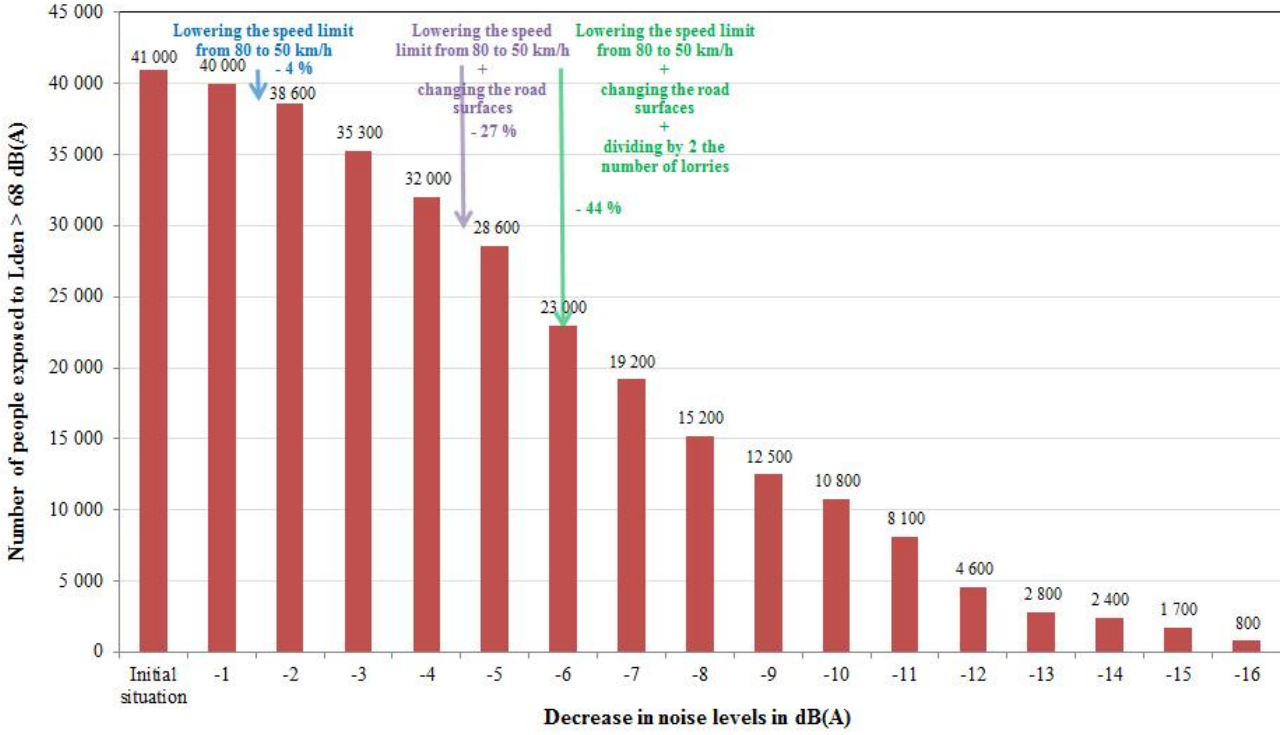

Figure 10: Estimation of the impact of actions against noise in terms of diminution of the number of people exposed over the threshold value for Lden indicator (68 dB(A))

Limiting peaks of noise generated at night by particularly noisy two-wheeled motor vehicles and the excessive use of sirens and horns should also be undertaken. These peaks of noise, with one-off noise events of up to 25 dB(A) at night have little impact on the calculation of noise indicators (Ln or Lden), which represent a noise average over long periods. They are nevertheless highly problematic in terms of quality of sleep because they can cause awakenings, whether conscious or not, for residents near the ring-road. In order to fight such uncivil behaviour, awareness-raising actions and repression should be reinforced.

For the 11,100 people living in dwellings exposed to noise levels exceeding 70 dB(A), that is to say more than 8 dB(A) over the night-time threshold value, localized complementary actions should be considered, like building anti-noise screens where technically feasible. Such measures indeed allow a decrease of noise levels on the façade of buildings by about 7 dB(A), at least for lower floors. Solutions for modifying outside façades, by setting up sloping balconies for example, can also be useful as they reduce noise levels at the flats' windows. Such solutions can be very effective for higher floors, as was proved by alterations made on a building in Asnières along a main road, which allowed a 6.5 dB(A) noise reduction on higher floors. (Source: Conseil général des Hauts de Seine).

Finally, from a more general point of view, sound insulation on the façades of buildings impacted by the ring-road should be encouraged, and it should be coupled with thermal insulation when the latter is planned, so as to allow greater comfort inside the homes.

These further studies, carried out by Bruitparif in 2010 and 2011 have contribute effectively to fuelling the thinking within the framework of the working group on the ring-road organized by the City of Paris within the framework of the preparation of its environmental noise action plan.

4. INSTALLATION OF PERMANENT NOISE MEASUREMENT STATIONS

So as to monitor the evolution of noise levels generated by the ring-road over time, especially in relation with the actions which will be implemented to reduce noise, Bruitparif decided to set up several permanent measurement stations.

The first one was set up in March 2011 in a situation of resident exposure in front of the building located at road Pierre Soulié, in the 20th arrondissement, on the outer side of the ring-road. This site had been chosen in the wake of the measurement campaign of 2009, as it was the site where the highest noise levels had been recorded.

A second sector has been monitored since the beginning of May 2012 between Porte de Vincennes and Pont de Lagny. Five stations were set up: one on the central reservation (near the source of noise), and four others on the front of buildings adjacent to the ring-road. This sector was chosen to be thoroughly documented as regards noise levels because the city of Paris made it the site of a great urban renewal project (GPRU) and of pilot measures to fight against noise (experiment of a new low-noise road surface since the end of June 2012). The data recorded by Bruitparif's measurement stations should highlight the impact of the various measures and of the layout implemented in terms of improvement of residents' sound environment.

Finally, a measurement station was set up at Porte d'Auteuil on the central reservation and close to Airparif's air quality measurement station. This station will be operational by mid-October and will allow a precise documentation of the relationships that exist between traffic conditions, levels of pollutants, and noise levels, and to highlight the combined impact of the expected evolutions in terms of traffic conditions (lowering traffic speed, change in the make-up of the vehicle fleet) on these two environmental issues.

The data from these measurement stations can be accessed in real time on the public display on internet from Bruitparif, the "Rumeur" site, http://rumeur.bruitparif.fr.

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