MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Health impact of noise in Greater Paris Metropolis: assessment of healthy life years lost

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ABSTRACT

Based on the strategic noise maps associated with road, rail and aircraft traffic (Directive 2002/49/EC), Bruitparif has deployed a method for assessing health impacts per square of territory (500 x 500 m²) and per municipality. This approach is similar to that used in 2011 by Bruitparif and the Regional Health Observatory in Île-de-France to assess health impacts in the Paris agglomeration in terms of healthy life years lost every year: DALY (disability-adjusted life-years). It adds two essential dimensions for public decision-makers: the results in space and the determination of sectors with priority issues.

The inhabitants of the Greater Paris Metropolis (GPM) lose on average 8 months of life in good health during their life because of their exposure to noise of transport. This value can reach 18 months for some municipalities. Bruitparif has developed a noise diagnosis for the GPM to prioritize areas with critical issues. This diagnosis serves for discussions with the partners concerned (municipalities, public institutions…) to confirm the priority sectors and identify the actions to be undertaken. This study contributes to identify the sectors to prioritize in the action against noise pollution related to transport in order to build the GPM's noise action plan (Directive 2002/49/EC).

Keywords: Heath, Environmental noise, Action plan
I-INCE Classification of Subject Number: 60 (Effects of noise / general)

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1. INTRODUCTION

The article initially planned concerned the study of the assessment of the health impact of noise in Greater Paris Metropolis (GPM), published in June 2018 by Bruitparif [10]. In February 2019, Bruitparif published the study at the scale of the Paris agglomeration which includes the territory of GPM [11]. This version also incorporates the new method of estimating health impacts proposed by the World Health Organisation in October 2018. This article presents the main results at the scale of the Paris agglomeration.

2. CONTEXT AND OBJECTIVE

Noise is a major source of annoyance in Île-de-France due to the high population density and the dense transport infrastructure. Noise is one of the main nuisances cited as impacting quality of life. Île-de-France is the most populous region of France with 12 million inhabitants in a surface area of 12,000 km², mainly concentrated in the region's densely populated zone, which has a population of 10.1 million. The majority of exposure to noise is caused by transport infrastructures, which are very highly developed and dense.

There is, therefore, great concern related to noise in Île-de-France. According to the results of one survey on 3,000 Île-de-France residents [1], three-quarters of the population of Île-de-France (76%) claim to be concerned about noise pollution (25% very concerned and 51% somewhat concerned), and one in three residents believe that noise is a major disadvantage of living in Île-de-France. One in four people even claim to have thought about moving house due to noise (24%). Noise is the second-biggest environmental nuisance cited by residents of Île-de-France, behind air pollution. It is a legitimate concern since the impact on health (hearing disorders, annoyance, fatigue, stress, sleep disturbance, increased cardiovascular risk, including high blood-pressure, and myocardial infarction, learning difficulties, etc.) are proven and recognised by the highest international health organisations. 54% of Île-de-France residents claim to be annoyed by noise at home, with this annoyance growing with the degree of urbanisation, on average 42% in the Seine-et-Marne department and 62% in Paris.

2.1 Strategic noise map

European directive 2002/49/EC of 25 June 2002 [2] pertaining to the evaluation and management of environmental noise requires all urban communities of more than 100,000 inhabitants to produce a strategic noise map (SNM) for their territory and update it every five years, as well as adopting an environmental noise action plan (ENAP). This directive has been transposed into French law and written into the environmental code. The noises taken into account are those related to road, rail, and airport infrastructures, as well as classified industrial facilities. Within the Île-de-France region, 14 urban agglomerations representing a total of 436 municipalities and 10.1 inhabitants are concerned: the Greater Paris Metropolis (131 municipalities, nearly 7 million inhabitants) as well as 13 "communautés d'agglomération"[6] or "communautés urbaines"[7] (cf. figure 1).

[6] Agglomeration communities.
[7] Urban communities.

Figure 1: 14 urban agglomerations representing the densely populated zone of Île-de-France region.

The so-called third-phase strategic noise maps were produced and supplied to each urban agglomeration concerned in 2018 by Bruitparif, Île-de-France's technical evaluation centre for environmental noise, with a view to their approval and publication. These strategic noise maps must also serve as a reference document for these local authorities to prepare their environmental noise action plans. To this end, and in order to help identify key priorities, Bruitparif has conducted an additional territorial diagnostic to evaluate the health impact of transport noise within all 14 urban agglomerations that make up the densely populated zone of Île-de-France.

2.2 From epidemiological studies to health impact assessment

Thanks to various studies that have been published on the topic at international level, the health impact of noise is now well and truly established. It goes beyond just the annoyance caused. Beyond the effects on the auditory system observed for high noise levels, several extra-auditory effects have also been identified, including sleep disturbance, cardiovascular disease and diminished learning capacity. Studies have also shown that noise is a factor that reinforces social inequality, with underprivileged populations also generally being those most exposed. In order to raise awareness of this major public health issue, we need to collect and publish quantified data for the region. That is why Bruitparif has evaluated morbidity connected to transport noise within the densely populated zone of Île-de-France.

Bruitparif used the methodology recommended by the World Health Organisation (WHO), based on the use of the indicator of healthy life-years (DALY - Disability-Adjusted Life-Years) lost, as well as the latest guidelines on environmental noise published by the WHO in October 2018 [6]. These guidelines define the recommended values for exposure to transport noise, as well as new exposure-response relationships that make it possible to compare levels of exposure to noise, as estimated by strategic noise maps, and the main health effects of noise.

Maps produced with a 250 m² grid, as well as at the level of the municipality, demonstrate the health impact of transport noise for the whole territory mapped as per European directive 2002/49/EC. Statistical results were provided for the area of study as a whole, as well as for each urban agglomeration, and for each municipality.

3. METHODOLOGY

The diagnostic was developed based on the latest knowledge on the effects of noise on health, published by the World Health Organisation (WHO) in October 2018 and using the methodology recommended by the WHO for quantifying the number of healthy life-years (DALY - Disability-Adjusted Life-Years) lost [3] [4] [6].

3.1 Recognised health impact of noise

Based on a wide review of the scientific literature, in its most recent publication in October 2018, the WHO claims that there is a robust and proven exposure-response relationships between populations' levels of exposure to noise and the rates of people who claim to be highly annoyed or have highly disturbed sleep. The strength of association for these relationships has been significantly upgraded (by a factor of 2 to 3) compared to the previous relationships available, especially for event-based noises like air traffic and rail traffic. The figure 2 shows the exposure-response curves now available for these effects and their variation compared to previous curves.

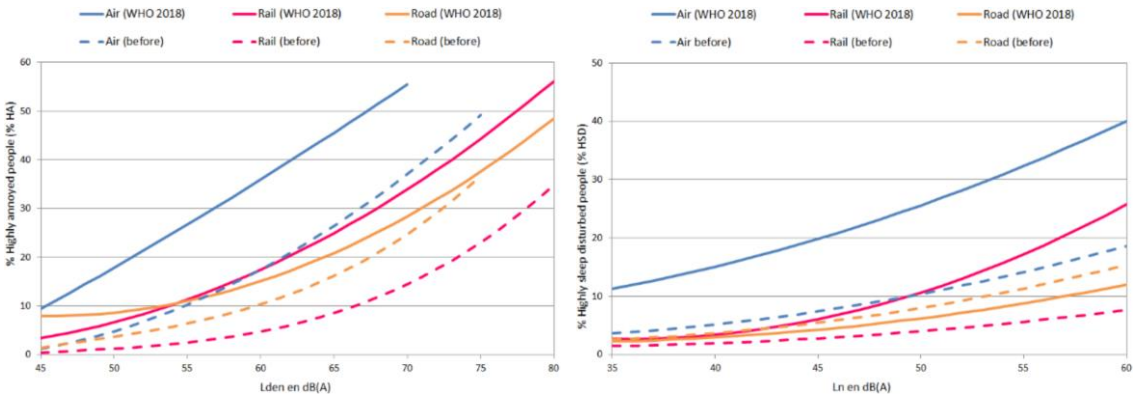

Figure 2: Exposure-response functions for annoyance (left graph) and sleep disturbance (right graph).

Other health effects of noise are considered critical by the WHO. In particular cardiovascular risk (coronary heart disease, high blood pressure, myocardial infarction) and learning difficulties. However, we do not currently have sufficiently robust exposure-response curves for these three sources of transport noise cumulated. Cardiovascular risk, for example, is well described for exposure to road noise but not yet sufficiently for rail and aircraft noise. As for learning difficulties, the available studies have mainly focused on young student populations subjected to aircraft noise pollution. For questions of homogeneity and coherence in the treatment of different noise sources, for this study, Bruitparif chose to only process the two best-documented effects, namely annoyance and sleep disturbance.

3.2 Noise indicators

The levels of exposure to noise used for these exposure-response curves are expressed using the indicators used in the strategic noise maps, namely Lden (noise weighted over 24h) and Ln (night-time noise for the 10 PM-6 AM period). The Lden indicator (which stands for Level day evening night) is an indicator of overall noise perceived over 24 hours which takes into account individuals' heightened sensitivity to noise in the evenings and at night. The Lden indicator is calculated using equivalent

average noise levels during the day (6AM-6 PM), in the evening (6 PM-10 PM), and at night (10 PM-6 AM) applying a weighting of +5 dB(A) and +10 dB(A) to noise in the evening and at night. It is calculated as an average over the year.

The Ln indicator (Level night) is the average noise energy over the night-time period (10 PM-6 AM). It is calculated as an average over the year.

3.3 Reference values

To protect the health of populations, in its October 2018 report, the WHO published guidelines concerning environmental noise, strongly recommending reducing exposure to transport noise to the levels below. The WHO's recommendations must be considered as targets to reach in order to minimise the negative effects of noise on populations.

Table 1: Values recommended by WHO.

Levels in dB(A)	Lden	Ln
Road noise	53	45
Rail noise	54	44
Air noise	45	40

France adopted regulatory limit values based on the framework of the transposition of European directive 2002/49/EC. Limit values are defined in European directive 2002/49/EC as a value of Lden or Lnight, and where appropriate Lday and Levening, as determined by the Member State, the exceeding of which causes competent authorities to consider or enforce mitigation measures; limit values may be different for different types of noise (road-, rail-, aircraft noise, industrial noise, etc.), different surroundings and different noise sensitiveness of the populations; they may also be different for existing situations and for new situations (where there is a change in the situation regarding the noise source or the use of the surrounding)".

The limit values set by France in application of the European directive are mentioned in the decree of 24 March 2006 and the order of 4 April 2006, pertaining to the creation of noise maps and environmental noise prevention action plans. For the sources of transport, they are as follows:

Table 2: French regulatory limits values.

Limit values in dB(A)	Lden	Ln
Road noise	68	62
Rail noise Conventional railway High speed railway	 73 68	 65 62
Air noise	55	-

It should be noted that France did not define a limit value for aircraft noise at night. Following this report, in the absence of a limit value for night-time traffic, we used the value of 50 dB (A). This value may be considered as critical considering the exposure-response curves provided by the WHO for sleep disturbance related to aircraft noise. 20% of people exposed to night-time noise levels of 50 dB (A) claim that their sleep is highly disturbed.

3.4 Disability adjusted life-years (DALY) lost values

Based on the data from strategic noise maps expressed using the Lden and Ln indicators, it was possible to calculate the number of people affected and people whose sleep was disturbed at any point in the territory, depending on the level of exposure to transport noise, using the previously mentioned dose-effect relationships recommended by the WHO.

This work continued with the evaluation of healthy life-years (disability-adjusted life-years, DALY) lost due to annoyance and sleep disturbance caused by transport noise. The DALY is a metric recommended by the WHO which quantifies the deterioration of populations' health due to disease or by exposure to environmental factors. The WHO estimates that annoyance can be translated by a health deterioration coefficient (also called disability weight) of 0.02, and 0.07 for sleep disturbance. The disability weights related to each health impact vary on a scale of 0 (undeteriorated health) to 1 (death). They were calculated based on expert opinions collected by the WHO.

It is thereby possible to convert the previously presented exposure-response relationships (cf. figure 2) into graphs that show the potential individual health risk depending on the level of exposure to noise. For this, the DALYs lost due to annoyance or sleep disturbance are calculated applying the corresponding disability weights and then applied to an individual whose exposure to noise would remain stable throughout their life. The figures provided are for an average individual with a life expectancy of 83.4 years, which is the average life expectancy for men and women living in Île-de-France (85.8 years for women and 80.9 years for men - source: INSEE 2014). The figure 3 shows the results obtained in numbers of healthy life-months lost due to noise during a lifetime for annoyance and sleep disturbance for exposure to each source of transport noise.

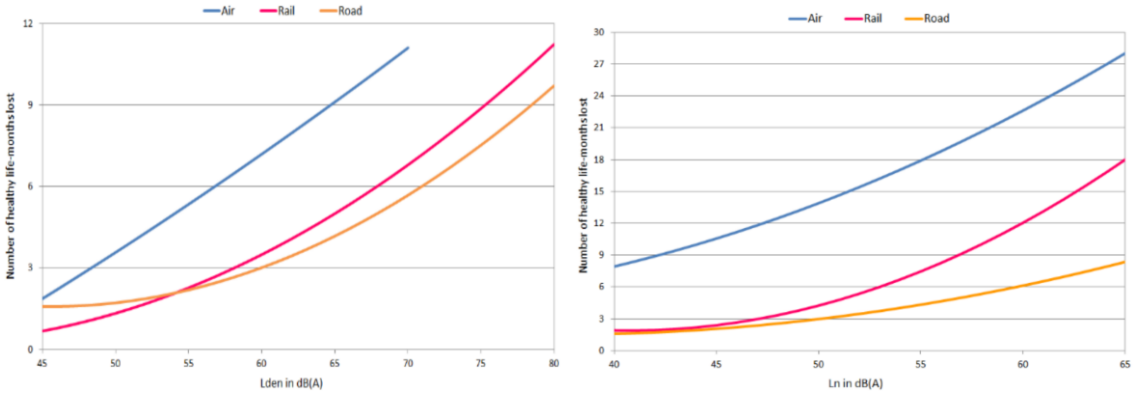

Figure 3: Healthy life-months lost due to noise during a lifetime for annoyance (left graph) and sleep disturbance (right graph).

By using these relationships, it is possible to convert strategic noise maps into potential individual health risk maps for the noise from each mode of transport and the cumulated transport noise. These maps give an idea of the scale of inconvenience caused by transport noise for an individual who lives their whole life within one part of the region (cf. figure 4).

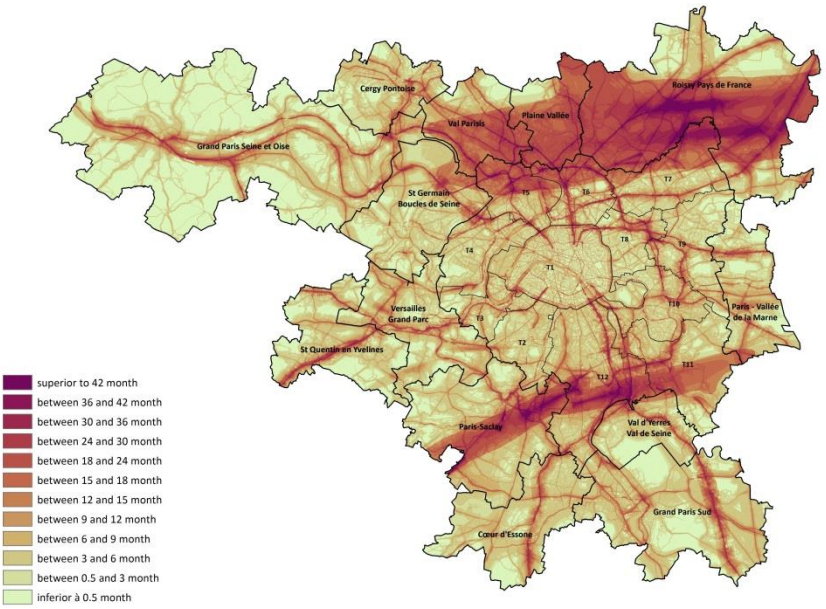

Figure 4: Potential of health risks for an individual due to cumulated transport noise exposure (number of healthy life-months lost during a lifetime).

3.5 Results produced

The study produces a certain number of results pertaining to the population's exposure to transport noise and its health impact, in the form of maps and statistics.

It was decided to present the results by noise source (road noise, rail noise, and aircraft noise) and cumulatively for the three sources. For each source, after a reminder of the main results from the strategic noise maps (population distribution by range of noise level and comparison with the different reference values), the health impacts are presented. By adding the values of disability-adjusted life-years lost combined with the annoyance and sleep disturbance values, with a 250 m² grid, as well as at municipality level, these maps illustrate the territorial distribution of disease caused by noise as well as the potential individual risks.

There are statistics presenting results for the entire territory and for each agglomeration, as well as for the 50 municipalities with the highest values, bearing in mind that results for every municipality are available in the full report [11]. The data is provided for each territorial unit as a total number of disability-adjusted life-years lost each year as well as the average individual risk (healthy life-months lost per individual over a lifetime).

These two types of information seem complementary in terms of the selection of the territory's priority sectors. The figure on disability-adjusted life-years lost per territorial unit provides information on the collective scale of disturbance, whereas the figure on healthy life-months lost at individual level over a lifetime represents the individual risk.

In order to take into consideration both of these aspects of health risks (collective and individual), Bruitparif has produced additional maps that highlight the territory's grids that have high values for both aspects. This ranking of grids was done using the so-called Euclidean distance technique. The grids that had the total DALY and individual risk values that were closest to the highest values observed were sorted in ascending order of Euclidean distance. The figure 5 illustrates the process used.

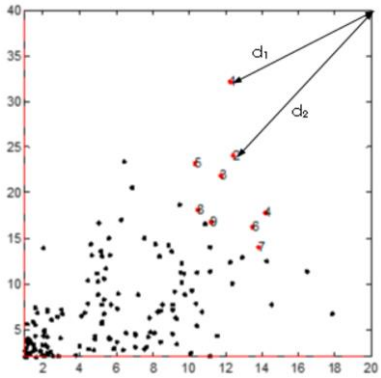

Figure 5: Process using Euclidean distance.

Once the ranking was completed, the 500 grids with the highest values were selected for each noise source. This ranking highlights the neighbourhoods that should be the priority in terms of public action to reduce noise pollution.

And finally, the results of the health impact and the related economic costs were compared with those obtained during the first evaluations conducted between 2011 [7] [8] and 2015 [9] by Bruitparif and the Île-de-France's regional health watchdog.

4. MAIN RESULTS

4.1 Regarding reference values

People within the densely populated zone of Île-de-France are highly exposed to transport noise throughout the day since nearly 90% of inhabitants (more than 9 million people) are exposed to noise levels that exceed those recommended by the World Health Organisation to avoid the health effects of noise. This trend can be seen through the many people who are subjected to noise levels that exceed the regulatory limit values for France in application of the noise directive: Nearly 1.5 million inhabitants (14.8% of the population) are exposed to noise levels that exceed at least one limit value for the Lden indicator.

Road traffic is the main cause, with 10.8% of inhabitants exposed to excessive road traffic noise. Exposure to noise levels exceeding limit values for aircraft and rail traffic is down (respectively 3.7% and 0.5%), but these two types of nuisances have proportionally higher health risks due to their event-related nature (succession of noise peaks). Noise levels generated by transport at night are falling. However, nearly 87% of the population still lives in accommodation exposed to outside noise levels that exceed one of the nocturnal quality objectives set by the WHO and 510,900 inhabitants (5.1% of the population) are even concerned by nocturnal levels that exceed one the regulatory limit values set for road or rail noise where the value of 50 dB(A) is believed to be critical for aircraft noise.

The majority of people exposed to transport noise (all sources) live in Greater Paris Metropolis. Among the inhabitants of the Paris agglomeration exceeding the limit values for the Lden and Ln indicators, respectively 71% and 74% live in the Greater Paris Metropolis. Outside of Greater Paris Metropolis, urban areas significantly affected by airport noise are home to the highest levels of people exposed to noise levels that exceed one of the limit values for Lden.

4.2 Regarding health impact

A majority of the municipalities with the highest numbers of healthy life-years lost due to cumulated transport noise are located in Greater Paris Metropolis, but there is also the city of Versailles, as well as cities in the Val d'Oise department that combine very densely populated areas and significant aircraft noise (cf. figure 6).

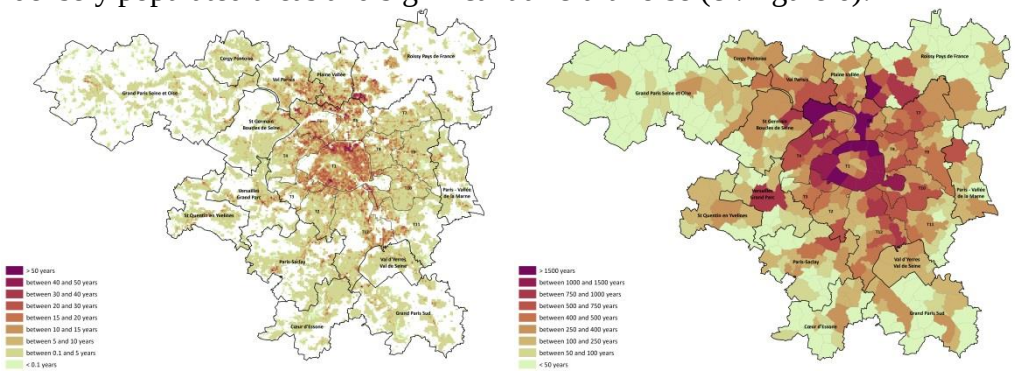

Figure 6: Cumulated transport noise - collective health impact - number of healthy life-years lost per year - grid of 250 m (left graph) - municipality level (right graph).

At individual level, the evaluations show an average statistical value of 10.7 healthy life-months lost during a lifetime per individual due to cumulated transport noise, within the densely populated zone of Île-de-France. There are, however, significant variations within the region, with the impact on healthy life-months lost per inhabitant ranging from 7.1 months to 24.5 months (a ratio of 1 to 3.45) depending on the territory or urban community, and varying from 2.6 months to 38.1 months (a ratio of 1 to 14.65) depending on the municipality. These significant variations highlight the impact of aircraft noise (cf. figure 7).

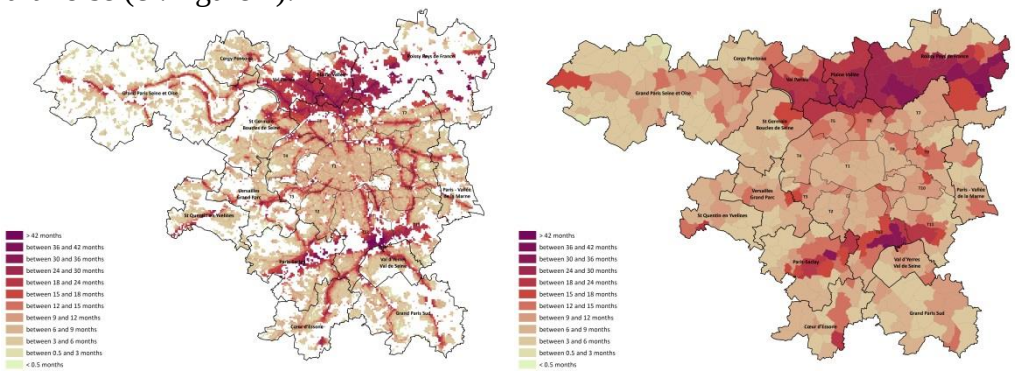

Figure 7: Cumulated transport noise - individual health risks - number of healthy life-months lost per individual during a lifetime (grid of 250 m and municipality level).

On average, inhabitants of the Greater Paris Metropolis lose 10.1 healthy life-months over their lifetimes - the health impacts per inhabitant ultimately being more moderate in areas concerned only by noise pollution from land transport – with values varying between 8.5 months (city of Paris) and 10.3 months (for T3 - Grand Paris Seine Ouest and T10 - Paris Est Marne et Bois). Within Greater Paris Metropolis, T6 - Plaine Commune (15 months), T5 - Boucle Nord de Seine (14 months), and T12 - Grand Orly Seine Bièvre (12.2 months), have the highest individual risks.

In total, in terms of the health impact, transport noise is responsible for the loss of 107,766 disability-adjusted life-years (DALYs) every year within the densely populated

zone of the Île-de-France region (cf. table 3), distributed between the DALYs lost due to annoyance (46,837, 43% of the total) and the DALYs lost due to sleep disturbance (60,929, 57% of the total). Road noise is responsible for 61% of the health impact (65,607 DALYs), followed by rail noise (23,440 DALYs, and 22%), and aircraft noise (18,718, 17%). 63% of these health impacts come from the Greater Paris Metropolis, with 68,216 DALY.

Table 3: DALY in Paris agglomeration.

DALY	Road	Rail	Air	Total
Sleep disturbance	33 613	15 088	12 227	60 929 (57%)
Annoyance	31 994	8 352	6 491	46 837 (43%)
Total	65 607 (61%)	23 440 (22%)	18 718 (17%)	**107 766**

4.3 Priority grids

The 1,500 priority grids (500 for road noise, 500 for rail noise, and 500 for aircraft noise) were selected (cf. figure 8) by choosing the grids that showed the highest combined collective health impacts and individual risk levels.

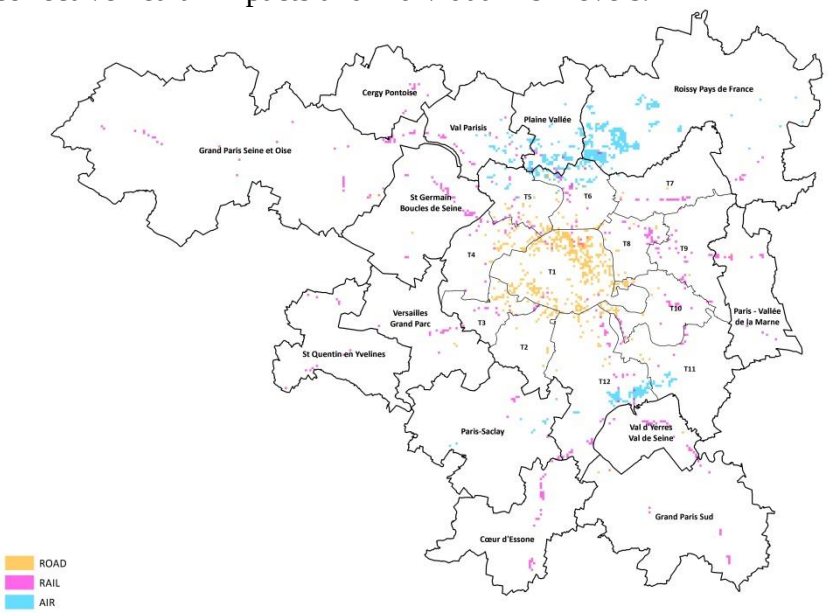

Figure 8: the 1500 priority grids.

Unsurprisingly, these grids reveal the issue related to high exposure to noise generated by road traffic in Paris, along the Paris ring-road, as well as along major motorways. Regarding rail noise, the priority grids highlight high levels of noise pollution generated by the dense rail network (in particular the Transilien network, and RER lines C, D, and E) over the whole region, as well as within the Paris city limits, up to the main stations. The priority grids are distributed fairly evenly along all overland rail lines when they cross highly urbanised areas. The health impact of air traffic has a strong impact on the municipalities of Val d'Oise located on the flight path of Paris-CDG airport, but is also high in the Seine-Saint-Denis department. And finally, there are some more dispersed zones located in Essonne department due to the activity of Paris-Orly airport, and in Seine-et-Marne due to overflights to and from Paris-CDG. Furthermore, sectors that are highly impacted by noise pollution from airports are not

always exempted from problems posed by rail and road traffic, and they sometimes accumulate high levels of all three sources of environmental noise.

5. UNCERTAINTIES FACTORS

There are uncertainties at every step of this method for assessing health impact. Several uncertainty factors have been identified.

The estimations for healthy life-years lost due to noise are based on data from the first noise maps produced under European directive 2002/49/EC. The quality of estimations is highly dependent on input data (traffic, speed, road surface, noise barriers, topography, etc.). Furthermore, the method for calculating the population's exposure appears to overestimate the values.

The WHO's 2011 qualification of the burden of disease from transport noise in Western Europe indicates that sleep disturbance and annoyance alone represented a total of 92% of the 1.62 million disability-adjusted life-years lost calculated. Not taking into account the effects of cardiovascular risks and learning difficulties in the evaluation therefore leads to a probable underestimation of the burden of disease from noise in the densely populated zone of Île-de-France of around 10%.

The WHO recommends evaluating disease caused by environmental noise using the Disability-Adjusted Life-Year (DALY) metric, using the recommended Global Burden of Disease (GBD) method. In this calculation, the choice of disability weight has a strong influence on the results. Based on an exhaustive study of several research projects carried out by the WHO's group of experts, the DW disability coefficient due to sleep disturbance was set at 0.07 to calculate DALY[8]. In the case of annoyance, the value of 0.02 leads to a "conservative" approach, where the emphasis is on underestimating disease. In their October 2018 report, the WHO indicates that the effects of annoyance and sleep disturbance due to a single noise source must be considered to be cumulative and that it is therefore possible to add the DALY values calculated for both annoyance and sleep disturbance for a single noise source.

The WHO also noted a relative lack of understanding of the effects of exposure to multiple sources of noise simultaneously, or the exposure to noise combined with other environmental nuisances (air pollution, for example). To present the results in this study, we decided to cumulate the health impacts of the three noise sources in the knowledge that this probably over-evaluates the effect.

6. CONCLUSION

With nearly 108,000 disability-adjusted life-years lost every year within the densely populated zone of Île-de-France, at an economic cost of €5.4 billion per year, the results obtained confirm the trends highlighted by the WHO at European level [5]. Noise pollution is the second-highest cause of morbidity among environmental risk factors in urban environments, behind atmospheric pollution.

These results have been compared with the previous evaluations carried out by Bruitparif and the Île-de-France regional health watchdog between 2011 and 2015. Estimations have been reviewed significantly upwards (from 75,000 to 108,000 DALYs, +43%), especially for aircraft noise (multiplied by a factor of 3.7) and rail

[8] The value chosen takes into consideration the statistical distribution of DW observed in various research projects studied whose variations translate an uncertainty interval of between 0.04 and 0.1.

noise (multiplied by a factor of 3.5), due to the use of new exposure-response relationships recommended by the WHO.

Adjusted to the level of an average citizen living within the densely populated zone of Île-de-France, healthy life-months lost over a lifetime now reach 10.7 compared to 7.3 for the 2015 estimation. Regional differences are also significantly exacerbated, with the individual health risk now reaching more than three healthy life-years lost in sectors that suffer from exposure to multiple aircraft and land sources, compared to 18 months in the 2015 estimation.

The study conducted by Bruitparif has therefore re-evaluated upwards the health and economic impact of noise in the densely populated zone of Île-de-France and, above all, has provided essential new information for public policymakers: the provision of results by territory, as well as the determination of priority areas. The ambition of this study is therefore to fully contribute to anticipating where to focus resources in the fight against noise pollution, by creating a reference document to help stakeholders prepare the various environmental noise action plans that the competent authorities will have to produce in 2019.

7. REFERENCES

1. *"Enquête Crédoc pour Bruitparif : Qualité de vie et nuisances sonores : opinions et comportements des Franciliens"*, Bruitparif, (2016)
2. *"Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise"*, EC, (2002)
3. *"Burden of disease from environmental noise - Quantification of healthy life years lost in Europe"*, JRC, WHO Regional Office for Europe, (2011)
4. T. Hellmuth, T. Classen, R. Kim, S. Kephalopoulos, *"Methodological guidance for estimating the burden of disease from environmental noise",* WHO Regional Office for Europe (2012)
5. F. Georges, M-E. Heroux, K. Fong, *"Public health and economic burden of environmental noise",* WHO Regional Office for Europe, Internoise 2013, Innsbruck, Austria (2013)
6. *"Environmental Noise Guidelines for the European Region"*, WHO Regional Office for Europe, (October 2018)
7. *"Health impact of noise in the Paris agglomeration: quantification of the healthy life years lost – Position paper on the application to the Paris agglomeration of the WHO method to determine the burden of disease from noise"*, Bruiparif, ORS Île-de-France, WHO Regional Office for Europe, (2011)
8. F. Mietlicki, S. Host, R. Kim, R. Da Silva, C. Ribeiro, E. Chatignoux, *"Health impact of noise in the Paris agglomeration assessment of healthy life years lost",* Bruitparif, ORS Île-de-France, WHO Regional Office for Europe, Internoise 2013, Innsbruck, Austria (2013)
9. *"Impact sanitaire du bruit des transports dans l'agglomération parisienne : quantification des années de vie en bonne santé perdues – Application à l'agglomération parisienne de la méthode de l'OMS pour la détermination de la morbidité liée au bruit"*, Bruiparif, ORS Île-de-France, (2015)
10. *"Diagnostic acoustique métropolitain - Préalable au Plan de prévention du bruit dans l'environnement"*, Bruitparif, (Juin 2018)
11. *"Health impact of transport noise in the densely populated zone of Île-de-France region"*, Bruitparif, (February 2019)