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Front cover: Winter in the Rhodopi Mountain, Chepelare, Bulgaria

EDITORIAL

Dear EURASAP members,

In this first issue for 2006 we stress on the relation of atmospheric research to the regulation of air pollution. To find more successful way to communicate science to policy makers, industry and general public is a real challenge to meet.

The Newsletter Editor

Scientists' Contributions

The challenges of air pollution in the transport sector (from the French case)

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Abstract

The main pollutants are listed for today and the future according to the progression of air quality, as measured in France and in the European Union during the last 15 years, to the progression of pollutant emissions of road transport in France, as calculated for the period 1970-2025, and to the progression of public concern regarding air pollution and environment. These pollutants are headed by carbon dioxide, followed by nitrogen oxides and then fine particulates. The stakes in terms of technology and transport supply and demand are assessed. These stakes for society allow us to propose several directions of research in the field of air pollution that respond more to current problems than those of the past (greenhouse effect, sensitive pollution, photochemical pollution, life cycle approach, aggregated indicators). In addition the new European tool Artemis for inventorying emissions from the transport sector is presented.

Keywords: transport emissions, air quality, abatement technology, research policy.

Introduction

One specific characteristic of research into air pollution and more generally into the environment is that the subjects dealt with strongly depend on social demand. This was the case for research into acid rain and then into the greenhouse effect, as well as into visibility over North American cities. Furthermore, the directions proposed by researchers cannot be confined to scientific interrogation alone (understanding that which is not understood), but must take into account the public issues involved in the area concerned. Regarding air pollution generated by transport, the progression of air quality, as well as that of emissions, which has the advantage that it can be extrapolated fairly reliably for the next twenty years, provide a wealth of information. Here, we attempt to highlight the present and future stakes and issues of air pollution by examining the French case, which is much the same as that of the European Union (except the percentage of diesel cars), and by consequence the priority subjects for research. Based on developed country data only, it is subsequently not allowed to extrapolate the conclusions to developing countries without care. Air pollution is understood here in a wide sense, including different air pollution types, characterized by different mechanisms, time and geographical scales, different primary pollutants, as sensitive pollution, local pollution with health effect, photochemical pollution, greenhouse effect…

The progression of air and road traffic emissions

Air quality

We now have a series of air quality measurements under comparable conditions over a sufficiently long period to be able to evaluate the progression of air quality with fairly good precision: more than four decades for sulphur dioxide SO_2 and black smoke, about fifteen years for most pollutants, though a little less for ozone O_3 (Airparif, 1999, Stroebel et ali, 2003).
Thus in the Paris region concentrations of SO_2 have fallen by a factor of about twenty since the 50s. Carbon monoxide and total hydrocarbon HC contents have decreased by a factor of four over the last ten years, whereas concentrations of black smoke fell by nearly 80% from the fifties to eighties before stabilising. It is nevertheless difficult to assess evolution of PM10 content, although some measurements show a considerable decrease (up to –80 % during the last 20 years). Nitrogen dioxide NO_2 contents remained fairly stable during the 90s and appear to have fallen over the last few years; the phenomenon appears to be more marked for peak urban nitrogen pollution. On the contrary, concentrations of carbon

dioxide CO_2 have risen. Lastly, ozone concentrations have not undergone significant changes over the last six years; however, although the averages do not appear to have changed much at all, the median of the annual averages has tended to increase. This could result in a geographical extension of the periods of photochemical pollution whose clouds often cover several thousand kilometres.

Consequently, it can be considered that air quality has improved globally, though not systematically. However, this appreciation does not correspond to the perception of the public, the majority of which considers, at least in France, that air quality has never been so bad and problematic (Roy, 2003). The environment is in fact an essentially personal conception based on the personal perception of the stakes involved, through our perception based on our senses (vision, smell) to which we add intellectual elements stemming from technical and scientific information we receive from the education system and the media, as shown by van Staëvel, 2000.

This personal construction is then organised by long term vision. Thus 65% of French people consider that technical progress in the 21st century will be made to serve sustainable development (Maresca & Hebel, 1999). Such sustainable development consists in handing on a viable environment and nature that is not a wilderness to future generations. Since the population is now far more aware of environmental stakes and the risks of pollution, air pollution considered as an environmental problem has therefore deteriorated, despite a relative decrease of concentrations.

Emissions

Although transport plays a minor role in SO_2 emissions, it contributes nearly one third of carbon dioxide emissions and almost two thirds of CO, NOx and the precursors of photochemical pollution, with substantial differences between regions. However, globally, transport has undergone strong growth (European Communities, 2004): in the European Union (15 Member States), all modes taken together, passenger transport – expressed in passenger-kilometre – has progressed respectively by 3.0 then 1.9% per year during the 80s and then 90s, with very similar figures for road transport taken alone. Moreover, with a progression of 8 and 6% per year resp. , the increase of air transport is even greater. During the 90s this corresponded to a doubling of traffic every 37 years for road transport and every 12 years for air transport.

In parallel, all modes taken together, freight transport – expressed in ton-kilometre – increased by 2.6% per year throughout the last three decades of the century, and by 3.4% for road transport alone, corresponding respectively to a doubling of traffic every 27 and 21 years.

The emissions of some pollutants should decrease according to the Convention of Long-range Transboundary Air Pollution, known as the Geneva Convention adopted in 1979 and entering into force in 1983, and its Protocols: the first Helsinki Protocol (1985, 1987: sulphur), the Sofia Protocol (1988, 1991: NOx), the Geneva Protocol (1991, 1997: NMVOC), and the multi-effect / multi-pollutant Gothenburg Protocol (1999: SO_2, NOx, NH_3 and NMVOC).

The progression is positive though contrasted for air quality, with strong simultaneous increases of traffic and concern over the environment. It is useful to give close examination to the progression of pollutant emissions to evaluate the consequences of increased traffic and technological improvements on air quality. This evaluation was carried out for the French situation, using the European inventory model Copert3 (Hickman et al, 1999). This model uses emission factors stemming from measurements made on vehicles up to the Euro 2 emission standard applicable until 2000. After this, emission factors have to take into account Euro 3 and Euro 4 standard through assumptions, especially for particle filters and accessories such as air-conditioning. Due to the lack of any concrete project with a longer time frame, no hypothesis for a further standard has been introduced. No specific account has been taken of innovative technologies such as hybrid engines and fuel cells. Road traffic forecasts up the year 2020 are derived from the median scenario (B) of the French Ministry of Transport (SES, 1998). This scenario B is the pursuit of the recent inflexion of passenger and good transport policy without strong changes. The scenario A is the pursuit of trends observed the last two decades; other scenarios assume further internalisation of external costs, pursuit of modal sharing, or a balancing of modal sharing to comply with future greenhouse agreements. The main parameters of the scenarios are economic, with different increases of fuel prices for instance. The different scenarios do not make any assumption on diesel share.

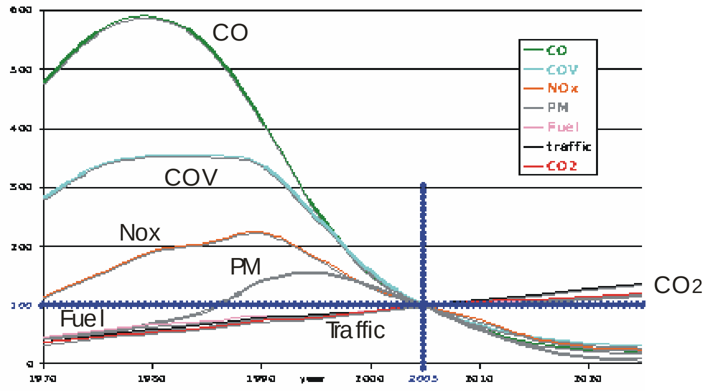

***Figure 1**: Relative evolution according to the figures of 2005 for French road traffic emissions from 1970 to 2025. Base 100 = year 2005 (Hugrel & Joumard, 2004).*

The results (Hugrel & Joumard, 2004 - cf. figure 1) are close to the official calculations (Fontelle et ali, 2003), despite some methodological differences. They show that following near stagnation during the 70s and 80s, CO and HC emissions fell by a factor close to four in 15 years. This very positive trend should continue in the years to come. It is due to the introduction of 3-way catalytic converters on gasoline vehicles and the increased number of light diesel vehicles that emit less CO and HC. It should be remembered that over the last thirty years, nearly one out of two vehicles sold in France is diesel, and now nearly 80 %.

The progression of NOx and particles is slightly different: they increased until the first 90s (particles increased by a factor of three in twenty years), then they decreased by nearly 40 %, a trend that should become firmer. This configuration can be explained by effects that act in contradiction with each other: the growth of traffic, increased use of diesel – a diesel engine emits three times more NOx than a gasoline engine with a catalytic converter – and very efficient catalytic converters. Progression in the future should be even more apparent for particles, which should be in 2025 four times lower than in 1970. It is due to the gradual introduction of very efficient filters. For these two pollutants, emissions from two-wheeled vehicles are absolutely negligible, while heavy goods vehicles emitted respectively 42 and 20 % of the total in 2005.

On the other hand the situation is particularly worrying for CO_2 (Fig. 3): Emissions progressed by nearly a factor 3 from 1970 to 2005, and should progress again by 20 % by 2025. This forecast does not take into account the possible introduction of technologies that consume only small amounts of fossil fuel such as hybrid cars and those equipped with fuel cells (but nevertheless they will not represent a large share in the 2025 fleet).

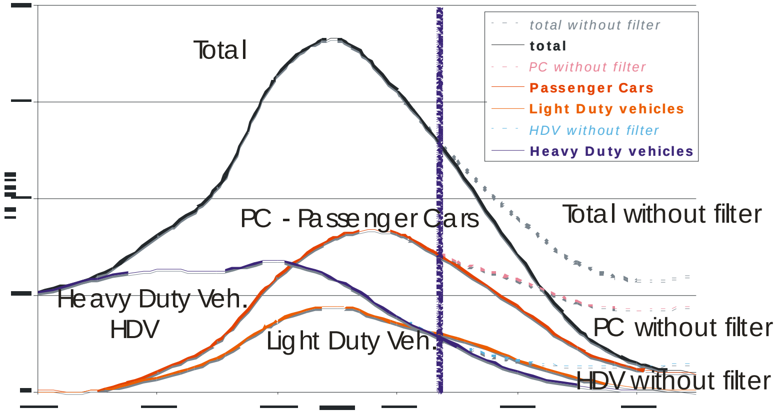

Figure 2: *Evolution of PM emission per type of road vehicle with and without the introduction of particle filter (Hugrel & Joumard, 2004).*

Although progressions are favourable for all the pollutants, apart from CO_2, the emission levels of all forms of transport are nonetheless much higher than those of the first half of the 20th century. The Swiss Environment Office (OFEFP, 1995) showed that emissions are now nearly 6 times higher for CO and THC, and resp. 10 and 14 times higher for CO_2 and NOx than during the first half of the 20th century. These factors reach respectively 170, 13 and 21 in comparison to 1900.

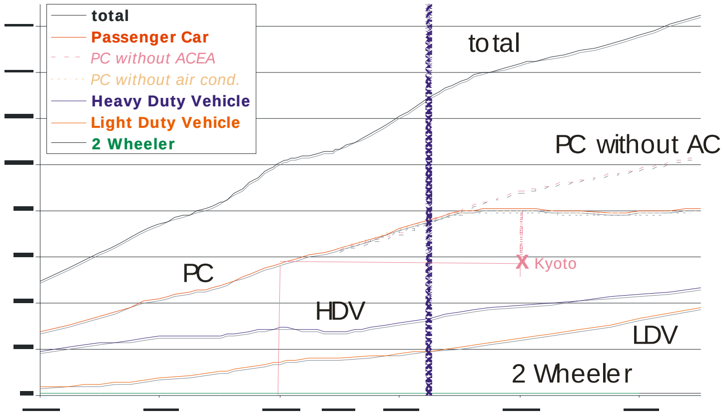

Figure 3: *Evolution of CO2 emission per type of road vehicle with and without the ACEA commitment, or air conditioning (Hugrel & Joumard, 2004).*

Note: *Coulor version can be seen at www.eurasap.org*

Technological stakes

Unit emissions

CO_2 emissions increase slightly less than traffic, meaning that on average unit emissions decrease. In the case for passenger cars the aggregate emission factor fell from 202 g/km in 1970 to 197 in 2000. This progression is due to the combination of highly significant improvements in engine technology with a parallel increase in vehicle weight, power and comfort which act in the opposite direction. On the other hand, average unit emissions have increased for motorised two-wheeled vehicles, increasing from 34 to 63 g/km in 35 years due to the increased numbers of powerful motorcycles that are partially replacing mopeds. Likewise, emissions by heavy duty vehicles have increased, rising from 745 to 1087 g/km from 1970 to 2005, corresponding to a vehicle weight increase. This growth should continue at a more moderate pace in the future.

Technologies

The main challenge concerns the reduction of unit emissions of carbon dioxide from light vehicles, motorcycles and heavy duty vehicles, and the continued reduction of nitrogen oxides and fine particles emitted by light diesel and heavy duty vehicles, without increasing emissions of other pollutants. These reductions should be considered for the entire lifecycle of vehicles and infrastructures, at least by incorporating the energy production system used and the uses of the vehicles.

European automobile constructors have undertaken to reduce the consumptions and average unit emissions of CO_2 of new private cars by 21% from 1995 to 2008 (ACEA agreement), gasoline and diesel taken together. However, this agreement is based on standard driving conditions and not on real-world conditions, and does not take into account car air-conditioning. This ACEA agreement will moderate the CO_2 emissions increase by the passenger cars from +60 % to +20 % between 1995 and 2025, but without complying with the Kyoto commitment: it stabilises only the emissions after 2005. Besides its slight negative effects on CO_2 emissions and other exhaust gases, air-conditioning suffers from leaks of cooling liquids that are also powerful greenhouse gases. By taking into account cooling liquid leaks, Ademe estimates that the ACEA agreement will not lead to the expected decrease of 2% of greenhouses gases emitted by private cars, but to an increase of 8% from 1995 to 2020 (Ademe, 1999).

Several technologies can or will be capable of reducing pollutant emissions.

The substitution of fuels. Increased use of diesel vehicles will lead to a probable reduction of CO_2 by 10 to 20%. The use of liquid petroleum gas (LPG) and natural gas would permit a reduction of CO_2 by 10 to 25% compared to gasoline, though this comparison would be slightly unfavourable in the case of diesel (IEA, 1999). The use of compressed natural gas (CNG) should have a very limited impact as it concerns nearly exclusively busses.

The filter for diesel vehicles traps particles at the exhaust outlet but gradually becomes clogged. Therefore it is vital to regenerate it periodically, something that appears to have been solved in a reliable way (Barbusse & Plassat, 2002). Many of the buses and heavy duty vehicles in circulation as well as new vehicles can be equipped with filters whose resistance is guaranteed through time. According to a large number of independent studies, all emissions of particles can be reduced, especially the finest which are most harmful for health, with an efficiency ranging from 90 to 99.9%. To get the very low PM emissions which we calculated for the future, the particulate filter must equip all the new diesel vehicles.

Direct gasoline injection aims at improving the engine's yield by injecting the fuel directly into the combustion chamber rather than into the intake manifold of the gasoline engine or into the combustion pre-chamber for diesel engines. Widely used for diesel engines, this technology appears promising for gasoline engines, though the first models on the market show only small savings for combustion and an increase of particle emissions. Savings in consumption from 10 to 15% are expected in time.

Supercharging consists in compressing combustion air. This permits the injection of higher volumes of fuel into a cylinder of equal volume and therefore increase the vehicle's power.

Future developments aim for gasoline vehicles to use supercharging to reduce engine volume without increasing power. Since consumption under urban conditions is practically proportional to engine volume, this permis reducing consumption.

Pure electric vehicles. These vehicles are zero emission ones, locally. But their market should be very small, due to a high cost of usage and a low range, which is the consequence of a low battery specific energy.

At present two main directions are being taken to introduce electricity in vehicle propulsion: hybrid vehicles and fuel cells (Yonnet & Badin, 2002).

The introduction of *hybrid vehicles* that associate a gasoline power train with an electric power train aims at improving the working conditions of internal combustion engine. The goal is to store the energy generated by the brakes in the batteries of the electric power train. This energy is lost in a traditional engine. It is also possible to charge the batteries by running the heat engine at a speed that guarantees its optimum efficiency, which is rarely the case under urban traffic conditions. This provides a saving of 30% under urban conditions, where the car drives often on electricity, but none on the highway (Jeanneret et ali, 1999).

Fuel cells constitute a direction for completely electric propulsion vehicles. They convert the chemical energy of hydrogen and oxygen directly into energy. When the vehicle consumes hydrogen, local emissions are nil. However, the only significant element is a balance that takes into account the hydrogen production section, which plays a major part. This well to wheel balance of cars propelled by fuel cells currently shows a saving close to 30% (if once considers the compressed hydrogen obtained from natural gas in the European Union), which may be cancelled in the next ten years by the progress made by traditional technologies (Antoine et ali, 2003).

The stakes of mobility

According to OECD estimates, the accelerated introduction of hybrid vehicles and fuel cells will not suffice to achieve ecologically viable forms of transport by 2050 (Wiederkehr, 1999). Only 40% of the effort required should focus on technology while the remaining 60% should focus on managing demand for transport and the adoption of more sustainable modes of transport. This implies major modal transfers to less pollutant modes such as walking, cycling and public land transport, and above all control over demand for the mobility of people and goods. As the traffic seems adapts itself to the supply of infrastructures, efforts should be made to control infrastructures. Without strong political will, none of these orientations will bear fruit.

Research issues

Apart from fundamental research, which remains necessary though participates little in research into air pollution in the field of transport, most of the research carried out on the subject has finalities, that is to say it explicitly aims at reducing the impacts of transport and its emissions of gases and particles into the atmosphere. This requires understanding of the psycho-sociological mechanisms at the core of the perception of the nuisances, the physical, chemical and biological mechanisms triggered by the impacts of pollution on different environments, including human, the mechanisms of emissions (from energy to transport economics), and lastly the political mechanisms involved in decision-making. The problems of this research are therefore directly linked to the nature of the impacts and importance of the stakes.

The problem of transport-generated air pollution is not that of the 70s or 90s and will be even less so in the next ten to twenty years, when the results of the research carried out today will have been applied. Therefore we must give priority to pollutants, impacts and the development of tools that are at the core of major challenges and progressively leave the other subjects to one side, even though uncertainty calls for prudence and thus very active monitoring.

In terms of pollutants, priority must first be given to greenhouse gases and especially carbon dioxide and thus the consumption of fossil fuels; secondly, NOx and the precursors of photochemical smog, since its progression can hardly be considered as being positive.

Regarding impacts, the greenhouse effect is undoubtedly the most important stake. Thus we should improve our knowledge, especially by taking into account a larger number of pollutants whose effects can vary as a function of their place of emission. The second impact in terms of magnitude is undoubtedly sensorial (odours, smoke, soiling) into which very little research is carried out, although all the surveys show that this is considered to be a major nuisance by the population. However, this aspect is somewhat lessened by the reduction of smoke emissions. Following this, mention can be made of photochemical pollution that is decreasing less than its precursors, which is rather astonishing, then the impacts on fauna and flora. Lastly, the problem of synergies between impacts, between different aspects of air pollution and different impacts on the environment has hardly been touched upon.

In terms of tools, a distinction can be made between emission tools, air quality tools and decision-aid tools. For emissions, priority should be given to macroscopic aspects by taking a life cycle type approach to the transport service. It should incorporate emissions from the production, utilisation and destruction of infrastructures, energy and vehicles. Socio-economic aspects are essential since, although unit consumptions are almost stable, the growth of traffic and its relation with economic growth raises problems.

The air quality tools should follow the stakes in terms of impact and focus on photochemical processes and greenhouse impact.

As for decision-aid tools, we cannot content ourselves with the analytical approach dear to the world of science, since it does not provide clear and simple answers, that is to say in an aggregated way, to the simple questions asked by both decision-makers and the community. It is particularly urgent to aggregate the different impacts composing air pollution, including pollution sensitive to the greenhouse effect and photochemical smog and even to take a systemic approach to the environment (including safety), for which the concept of sustainable development could be promising. This approach would gain from researchers sharing a common culture vis-à-vis all aspects of transport generated air pollution, the environment and transport.

Conclusion

Uncertainties regarding the progression of concentrations of different pollutants remain important given the short time-span involved, and when taking into account the large number of pollutants for which no regulations exist, this time span is very short. Certain of these pollutants may become apparent soon, such as carbon dioxide, which has transformed from an inert gas into a major pollutant in a few years. These uncertainties are as great for emission inventories, for non-regulated pollutants and also because we may have ignored an important source of emission.

We should therefore be careful when making conclusions and orienting research. In particular it would be unwise to abandon areas of research that may become important in a few years, contrary to current thinking. However, several strong and unquestionable directions of research remain, focused on the problem of the greenhouse effect, which we are beginning to understand but do not know how to solve. Moreover, systemic approaches to air pollution and the pair environment-transport appear interesting. They should allow better response to the problem of sustainable development than current approaches of an essentially analytical nature.

This analysis is based on Western European realities which can vary significantly from those of Eastern Europe, and emerging and developing countries. Therefore conclusions cannot be extrapolated without analysis.

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References

Ademe, 1999. Impact comparé de la mise en place de l'accord ACEA et de la pénétration de la climatisation automobile (Compared impact of the ACEA agreement and of the automobile air conditioning penetration). Ademe note, Paris, 27 May 1999, 11 p.

Airparif, 1999. Les tendances de la pollution de l'air en Île-de-France (Trends of air pollution in Paris region). Airparif actualité, June, Paris, 6p.

Antoine L., Martorana, E,. Badin, F., 2003. Évaluation du bilan en émissions de gaz à effet de serre d'un autobus à pile à combustible (Well to wheel evaluation of greenhouse gases emissions of fuel cell busses). Inrets report, Bron, France, n°LTE 0330, 250 p.

Barbusse S., Plassat, G., 2002. Les particules de combustion automobile et leurs dispositifs d'élimination (The automotive combustion particles and their elimination). Ademe report, Paris, 42 p.

Barbusse S., Gagnepain, L., 2003. La climatisation automobile, impact énergétique et environnemental (Automobile air conditioning: energy and environmental impact). Données et references, Ademe report, Paris, 8 p.

European Commission, 2004. EU energy and transport in figures, statistical pocketbook 2004. EC, Luxembourg, 220 p.

Fontelle, J.P., Allemand, N., Chang, J.P., Oudart, B., Audoux, N., Béguier, S., Druart, A., Duval, L., Gaborit, G., Sambat, S., Vincent, J., 2003. Inventaire des émissions de polluants atmosphériques en France - Séries sectorielles et analyses étendues - Format Secten (Inventory of atmospheric pollutant emissions in France – Sector data and detailed analysis – Secten format). Citepa report, Paris, 225 p. www.citepa.org/emissions/ france_objectifs/Secten_2002_v06mai.pdf

Hickman, J., Hassel, D., Joumard, R., Samaras, Z., Sorenson, S., 1999. Meet - Methodology for calculating transport emissions and energy consumption. European Commission, DG VII, ISBN 92-828-6785-4, Luxembourg, 362 p. http://vergina.eng. auth.gr/mech/lat/ or www.inrets.fr/infos/cost319/index.html

IEA, 1999. Automotive fuels for the future. Int. Energy Ag. report, Paris, 92 p.

Jeanneret B., Harel, F., Badin, F., Trigui, R., Damemme, F., Lavy, J., 1999. Évaluation des performances du véhicule Toyota Prius (Evaluation of the performances of the Toyota Prius car). 4th conf. C-VELEC, Grenoble, 3-4 nov. 1999, INPG, Grenoble, France, p. 168-178.

Hugrel, C., Joumard, R., 2004. Transport routier - Parc, usage et émissions des véhicules en France de 1970 à 2025 (Road transport - Fleet, use and emissions in France from 1970 to 2025). Inrets report, Bron, France, n°LTE 0420, 138 p.

Maresca B., Hebel, P., 1999. L'environnement, ce qu'en disent les Français (Environment, what tell the French). Documentation Française, Paris, 218 p.

OFEFP, 1995. Émissions polluantes dues à l'activité humaine en Suisse de 1900 à 2010 (Pollutant emissions due to human activities in Switzerland from 1900 to 2010). Cahiers de l'Environnement 256, 122 p.

Roy, A., 2003. La sensibilité des Français à leur environnement de proximité (French attitudes to the immediate environment). Données Environ., Ifen, Orléans, France, 85, p. 1-4.

SES, 1998. Les données détaillées du SES - le marché des véhicules (Detailed data of the vehicle market). Ministère des transports, DAEI-SES, Paris, 1998.

Stroebel, R., Bouallala, S., Colosio, J., Fangeat, E., 2003. Quelques données sur l'évolution de la qualité de l'air en France (Some data on air quality evolution in France). Pollution Atmosphérique, special issue, Nov. 2003, 9-21.

van Staëvel, E., 2000. Cultures environnementales contemporaines et pollution (Present-day environmental cultures and pollution). Rencontres européennes pour une histoire de l'environnement, Clermond-Ferrand, France, 4-6 mai 2000.

Wiederkehr, P., 1999. Environmentally sustainable transport: report on phase II of the OECD EST project. OECD report, ENV/EPOC/PPC/T(97)1/final, Paris, 100 p.

Yonnet, J.P., Badin, F. (éd.), 2002. Véhicules électriques et hybrides, enjeux technologiques et perspectives (Electric and hybrid vehicles: technology stakes and prospects). 5th symposium C-VELEC, Grenoble, 25-26 juin 2002, Inrets proceedings 84, Bron, France, 200p.

On the height of stacks with low pollutant emissions: analysis of data from a significant number of small and medium sized industries

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Abstract

Atmospheric dispersion modeling has proven its importance in giving a greater insight on the atmospheric distribution of pollutants. The good results obtained in the validation tests made with different dispersion models assure, to some extent, their applicability in the study of different scenarios of atmospheric pollutants emissions and in justifying design options which are unconventional and/or fall out of the legislation scope.

Due to the complex nature of the atmospheric dispersion phenomenon, a great deal of caution is yet necessary even in the application of validated dispersion models. A particular example is related with the application of dispersion models when perturbations in the airflow around industrial buildings have a significant impact in the pollutants dispersal, giving origin to building downwash effects. Building downwash problem is particularly important in existing small and medium industries that didn't pay much attention to pollution dispersal in the past and have stacks and building roofs of identical height and roofs of complex geometry, resulting from a seemingly unplanned growth of the productive process. Based on data gathered from a significant number of small and medium sized Portuguese industries, a comprehensive study on the need to heighten stacks with low pollutant emissions is presented. This study considers the application of the recent Portuguese legislation for stack height verification and the application of dispersion modeling tools. The main reasons for stack heightening in existing small and medium sized industries with low pollutant emissions are presented and discussed. The benefits and the environmental impact of the recent Portuguese legislation for stack height verification are discussed.

Keywords: Stack height, Legislation, Building downwash, Dispersion modelling.

Introduction

Since the introduction of the Air Act in 1990, several existing Portuguese industries had to review their stack height. Based on the applicable legislation, stacks should have more than 10 m, and, when in the vicinity of a large structure, and are given by equation (1).

$$A_c = a + 1{,}5l \qquad (1)$$

where, Ac stands for the stack height measured above soil (m), a stands for the nearby structure height measured above soil (m) and l stands for the smallest dimension (height or width) of the nearby structures (m), should be used.

Equation (1) did not take into account pollutant mass flow, upward thermal forces, background pollutant concentration and presented a quite crude way of dealing with the presence of large structures near the stacks. The conservative nature of this equation and the fact that Portuguese industries are generally small and medium sized enterprises with low pollutant emissions to the atmosphere, often led to disproportionate heightening needs that contradicted common sense.

As this legislation considers the possibility of justifying heightening needs based on dispersion modeling tools, this became the way used by several industries to avoid the conservativeness of equation (1). As a result, some lack of standardization in the stack height verification methodology occurred, and in some cases the importance of building downwash phenomena may have been neglected.

With the introduction of a new Portuguese legislation for stack height verification, pollutant mass flow, upward thermal forces and pollutant background concentration will be considered, and a more reasonable way of dealing with the influence of nearby large structures will also be considered. This constitutes a significant improvement towards the standardization of stacks height verification methodology and towards better environmental conditions.

Based on data gathered from approximately 100 stacks of more than 20 different Portuguese small and medium sized industries, and considering different methodologies to verify/compute stack height - recent Portuguese legislation; building downwash analysis and dispersion modeling, it is possible to assess the main reasons for stack heightening needs in existing small and medium sized industries. By comparing different methodologies for verifying and computing stack height, it is also possible to discuss the benefits and the environmental impact of the recent Portuguese legislation for stack height verification.

This paper is organized as follows: in section 2 the small and medium sized industries from where the data was collected are briefly characterized. Section 3 addresses the stack heightening needs considering the use of the recent Portuguese legislation. Section 4 presents a methodology - that considers building downwash phenomena and dispersion modeling - that has been used by the authors to verify the heightening needs of low pollutant emitting stacks, and compares the stack heightening needs using this methodology with the one obtained considering the recent Portuguese legislation. Section 5 discusses the benefits and the environmental impact of the recent Portuguese legislation for stack height verification.

Characterization of the industries considered in the study

The data used to assess the stack heightening needs in small and medium sized industries was collected since 1998, from over 20 Portuguese enterprises. These enterprises included glass manufacturers, chemical industries, combustion facilities, paper mills, and many other small and medium sized factories. Overall, more than 100 stacks were analyzed.

Different pollutant emissions were studied. However, the major pollutant mass flows emitted to the atmosphere were PM10 and NO_x. For these stacks, Figure 1 presents the relative frequency of different classes of PM10 mass flows emitted to the atmosphere, $\dot{m}_{PM10}$. From Figure 1 it can be concluded that more than 50% of the PM10 emissions were smaller than 100 g/h. Over 90% of the PM10 emissions were smaller than 1000 g/h.

Figure 2 presents the relative frequency of different classes of NO_x mass flows emitted to the atmosphere, $\dot{m}_{NO_x}$ .From Figure 2 it can be concluded that 45% of the NO_x emissions were smaller than 100 g/h; 65% of the NO_x emissions were smaller than 1000 g/h.

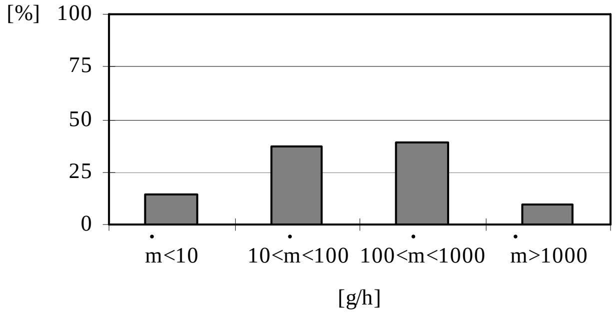

Figure 1. *Relative frequency of different classes of PM10 mass flows.*

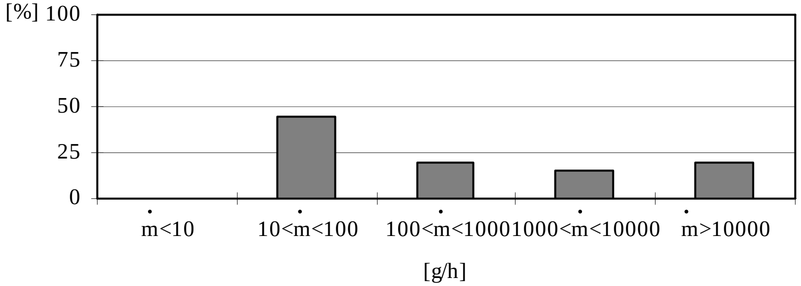

Figure 2. *Relative frequency of different classes of NOx mass flows.*

Figures 1 and 2 show that the majority of the stacks studied emitted low mass flows of pollutants.

Stack heightening needs considering the use of the recent Portuguese legislation

According to the recent Portuguese legislation, stack height verification depends on a minimum 10 m stack height and on: i) the magnitude of pollutants mass flow; ii) the presence of large structures in the vicinity of stacks; and, iii) the height of the stack above the top of the buildings roof where the stack is located (should be greater than 3 m).

For the studied stacks, Figure 3 presents the relative frequencies of different stack heightening needs, when only the magnitude of the pollutants mass flow is analyzed (note that heightening needs are presented as a percentage of heightening when compared to the actual stack height). From Figure 3 it can be concluded that, if the magnitude of pollutant mass flow emitted to the atmosphere was the only factor determining stack height, the majority of the actual stacks could in fact be lowered ($a_{\dot{m}}$ <0). Only 8,5% of the stacks studied had to be raised from its actual height ($a_{\dot{m}}$ =0) up to twice the actual stack height ($a_{\dot{m}}$ =1).

Figure 4 presents the relative frequencies of different heightening needs, when only the presence of large structures in the vicinity of stacks is analyzed. From Figure 4 it can be concluded that, if the presence of obstacles was the only factor in determining stack height, the majority (74%) of the actual stacks had to be raised to a height from its actual height ($a_{Obst.}$ =0) up to twice the actual stack height ($a_{Obst.}$=1).

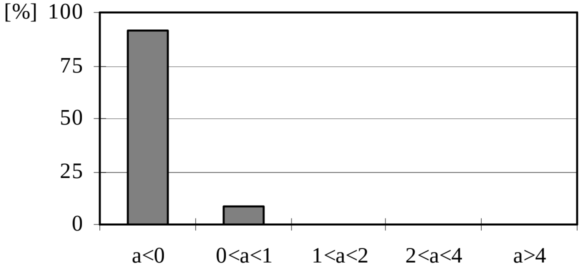

Figure 3. *Relative frequency of different classes of stack heightening needs,* $a_{\dot{m}}$ *, when only the magnitude of the pollutant mass flow is analysed.*

Figure 5 presents the relative frequencies of different stack heightening needs, when only the distance between the stack top and the top of the buildings roof where the stack is located is analyzed (should be greater than 3 m). From Figure 5 it can be concluded that only 30% of the stacks are 3 m (or more) taller than the roof top. The majority of the stacks studied (70%) should, however, be heightened, since their height above the roofs top is lower than 3 m.

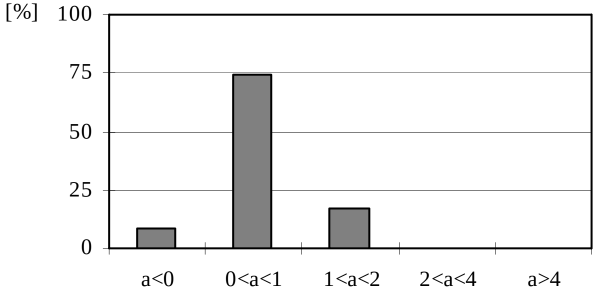

Figure 4. *Relative frequency of different classes of stack heightening needs, $a_{Obst.}$, when only the presence of large structures in the vicinity of stacks is analysed.*

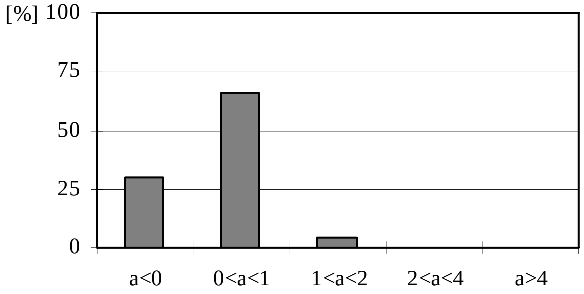

Figure 5. *Relative frequency of different classes of stack heightening needs, a_{Roof}, when only the distance between the stack top and the top of the buildings roof where the stack is located is analysed.*

Considering the three factors studied above, that determine the stack heightening needs, according to the recent Portuguese legislation, Figure 6 presents the percentage of stacks that should be heightened due to: i) the magnitude of pollutant mass flow ($\dot{m}$); ii) the presence of large structures in the vicinity of stacks (Obst.); and, iii) the height of the stack above the top of the buildings roof where the stack is located (Roof).

From Figure 6 it can be concluded that the main reason for the heightening of stacks of small and medium sized industries, with low pollutant emissions, is the presence of obstacles in the vicinity of stacks. Heights of stacks above the roofs top lower than 3 m are also a common reason for stack heightening needs.

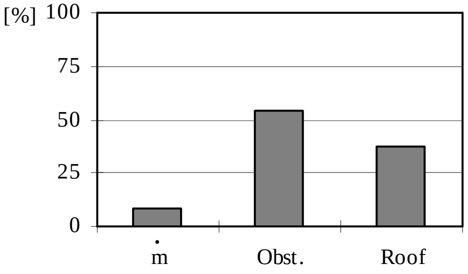

Figure 6. *Percentage of stacks heightening needs per factor: pollutant mass flow, $\dot{m}$; presence of obstacles, Obst., distance to roof top, Roof.*

Stack heightening considering building downwash phenomena and dispersion modeling

Experience in atmospheric pollutant dispersion modeling applied to Portuguese industrial facilities has been gathered by the authors since 1986. The methodology followed in these dispersion modeling studies is presented in detail by Gomes and Duarte (2004). This methodology begins with a site visit and gathering of data. With the plant layout data and the information from the site visit, a preliminary analysis on the airflow patterns around the main buildings can be performed. This analysis intends to identify possible building downwash phenomena. To study the compliance with ambient pollutant concentration limits, a gaussian dispersion model is used to determine ambient pollutant concentrations that result from specific maximum emissions, stack geometry and location (near large buildings) and meteorological data.

For the studied stacks, Figure 7 compares the stack heightening needs when this methodology is used and when the recent Portuguese legislation is followed. This comparison is presented in terms of differences (d, in percentage) using both methods. Five classes of differences were considered. From Figure 7 it can be concluded that in 50% percent of the studied cases there is a difference lower than 5% between the stacks heightening need obtained using the author's methodology and that obtained using the recent Portuguese legislation. In 87% of the cases this difference is lower than 10%.

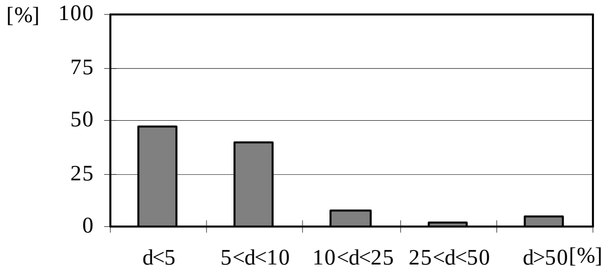

***Figure 7.** Difference between stack heightening needs using the author's methodology and the recent Portuguese legislation.*

When the recent Portuguese legislation method for determining the stack heightening needs is compared with the method based on equation (1), in 65% of the cases the differences in stack heightening needs between both methods are greater than 25%. This result points out the difference between the recent and old Portuguese methodology for verifying stack height.

Conclusion

In this paper, data gathered from a significant number of Portuguese small and medium sized industries was analyzed and the issue of heightening needs of low pollutant emitting stacks was addressed. The recent Portuguese legislation on stack height verification was applied to the data gathered. Results showed that for small and medium sized industries stacks usually emit low pollutant mass flows. For these industries the main reason for stack heightening needs is the presence of large obstacles in the vicinity of stacks. Small distances between stacks top and buildings roof top is also a common reason for stack heightening needs. Both results point out the importance of building downwash analysis when studying low pollutant emitting stacks.

A comparison between recent and old Portuguese legislation for verifying stack height showed great differences. When the recent Portuguese legislation was compared with the methodology that has been used by the authors (which considers building downwash phenomena and dispersion modeling tools), very similar stack heightening needs were obtained. This is obviously due to the importance given in both methods to building downwash analysis.

The fact that recent Portuguese legislation justifies reasonable heightening needs for low pollutant emitting stacks contributes to the swift enforcement of the legal requisites. Therefore, it contributes, also, to the reduction of the environmental impact of many small and medium sized Portuguese industries.

References

Gomes, J.F.P., Duarte, R., 2004. The importance of building downwash in assessing the need to heighten stacks of existing small and medium sized industries. Proc. of the 9th Int. Conf. on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes (vol. 1), ed. Suppan, P., Forschungszentrum Karlsruhe GmbH, Karlsruhe, pp. 282-286.

Calendar

28th NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Application, 15-19 May 2006, Leipzig, Germany, http://www.dao.ua.pt/itm, e-mail: itm@ua.pt, itm2006@tropos.de; Extended abstracts by 1 February 2006.

6th International Conference on Urban Climate (ICUC6), Göteborg, Sweden, June 12 – 16, 2006, http://www.gvc.gu.se/icuc6/, Extended abstracts by 10 April 2006.

To read in Issue 59

Past events,
Elisa Canepa, Emilia Georgieva and Corrado Ratto - First international conference on harbours and air quality (h&aq), 15-17 june 2005 - Palazzo san Giorgio, Genova (Italy),

Scientist's contributions, ***2***
Michael Poreh - On the effect of venting corridors on the urban canopy,