THE CHALLENGES OF AIR POLLUTION IN THE TRANSPORT SECTOR, FROM THE FRENCH CASE

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Regarding air pollution (in a wide sense) 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.

1 – 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 (Stroebel et ali, 2003). Thus in the Paris region SO_2 concentrations have fallen by a factor of about 20 since the 50s. Carbon monoxide CO and total hydrocarbon HC contents have decreased by a factor of 4 over the last 10 years, whereas concentrations of black smoke fell by nearly 80% from the 50s to 80s 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 6 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. 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. This personal construction is then organised by the long term vision of the sustainable development. 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 CO_2 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: in the European Union (15 Member States), all modes taken together, the increase of the passenger transport – expressed in passenger-kilometre – during the 90s 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, the freight transport – expressed in ton-kilometre – increase corresponded to a doubling of traffic every 27 years (21 years for road traffic).

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 Copert 3 (Hickman et ali, 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. No specific account has been taken of innovative technologies such as hybrid engines and fuel cells, but they will not represent a large share in the 2025 fleet. Road traffic forecasts up the year 2020 are derived from the median scenario of the French transport department (SES, 1998), corresponding to the pursuit of the recent inflexion of passenger and good transport policy without strong changes.

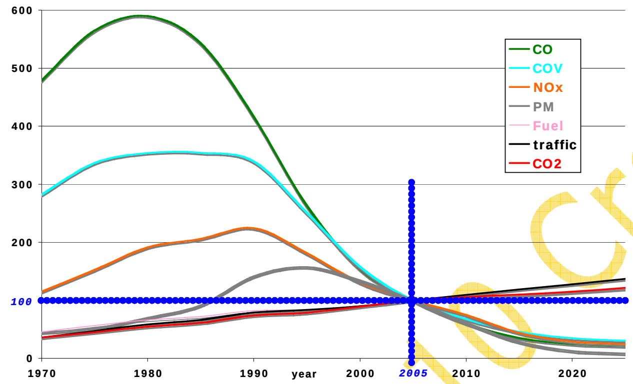

Figure 1:

Relative evolution according to the figures of 2005 for French road traffic emissions from 1970 to 2025. Base 100 = year 2005.

The results (Hugrel & Joumard, 2004 - see fig. 1) show that following near stagnation during the 70s and 80s, CO and HC emissions fell by a factor close to 4 in 15 years. This very positive trend should continue in the years to come. It is due to the introduction of continuously improved 3-way catalytic converters on gasoline vehicles and the increased number of light diesel vehicles. The progression of NOx and particles is slightly different: they increased until the first 90s (by a factor 3 in 20 years for PM), 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 3 times more NOx than a gasoline one) and very efficient catalytic converters. Progression in the future should be even more apparent for particles, which should be in 2025 4 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.

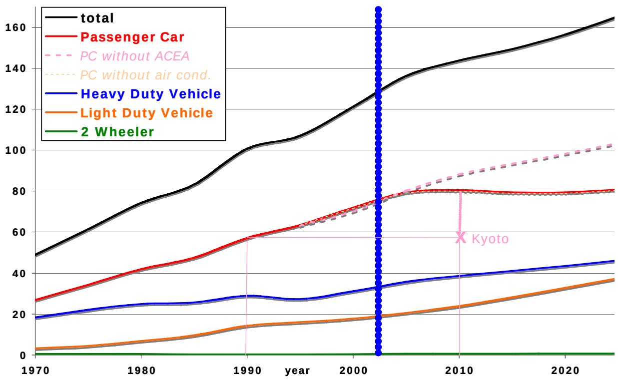

Figure 2:

Evolution of CO_2 emission per type of road vehicle with and without the ACEA commitment, or air conditioning

On the other hand the situation is particularly worrying for CO_2 (Fig. 2): emissions progressed by nearly a factor 3 from 1970 to 2005, and should progress again by 20 % by 2025. European automobile constructors have undertaken to reduce the average CO_2 emissions 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. It should in fact only 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 these leaks, the ACEA agreement should lead to a much higher increase of greenhouse gas emissions (Ademe, 1999).

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 20^{th} 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 20^{th} century.

2 – Technological and mobility stakes

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 2005. It 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 increased for 2-wheelers from 34 to 63 g/km in 35 years due to the increased number of powerful motorcycles that are partially replacing mopeds. Likewise, emissions by heavy duty vehicles increased from 745 to 1087 g/km from 1970 to 2005, corresponding to a vehicle weight and power increase. This growth should continue at a more moderate pace in the future. The main challenge concerns the reduction of unit CO_2 emissions all vehicle types, and the continued reduction of NOx and fine particles emitted by diesel 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 real uses of the vehicles. 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 and NOx by 11 and 50 % resp. compared to gasoline, though this comparison would be slightly unfavourable in the case of diesel for CO_2 (Gagnepain, 2004). The use of compressed natural gas (CNG) should have a very limited impact as it concerns nearly exclusively busses.

The particulate filter for diesel vehicles: 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 % (Barbusse & Plassat, 2002). 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.

S*upercharging* consists in compressing combustion air. Future developments aim for gasoline vehicles to use it to reduce engine volume without increasing power, and then to reduce consumption.

The *pure electric vehicles* are zero locally emission, 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. Therefore hybrid vehicles and fuel cells are at present two main directions to introduce electricity in vehicle propulsion (Yonnet & Badin, 2002). *Hybrid vehicles* provide a saving of 30 % under urban conditions, but none on the highway (Jeanneret et ali, 1999). *Fuel cells* convert the chemical energy of hydrogen and oxygen directly into energy. When we take into account the hydrogen production section, which plays a major part, the well to wheel balance of cars propelled by fuel cells currently shows a saving close to 30 %, which may be cancelled in the next ten years by the progress made by traditional technologies (Antoine et ali, 2003).

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 polluting 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 infrastructure supply, efforts should be made to control infrastructures. Without strong political will, none of these orientations will bear fruit.

3 – Research issues

Apart from fundamental research, most of the research carried out on the subject is aiming at reducing the impacts of transport and its emissions of gases and particles into the atmosphere. 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, especially altitude. 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. It requires understanding of the psycho-sociological mechanisms at the core of the perception of the nuisances, and lastly of the political mechanisms involved in decision-making. 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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