# Summary

**The transport sector is a major emitter of substances harmful to health, including $NO_x$, volatile organic compounds and particulate matter. Transport emissions make up an increasingly larger proportion of particulate matter as particle size decreases. In recent years transport emissions have fallen more than emissions in other sectors, mainly due to European policies in this area. The technologies available for the Euro 6 and Euro VI standards, such as particulate filters and SCR catalytic converters, are highly effective. If they are used properly, and this continues, they can reduce emissions and ambient concentrations of these air pollutants even further in future. In addition, cheap technical measures are still possible in the inland and maritime shipping sectors. Because the concentration of pollutants in the air is partly determined by foreign emissions and the formation of compounds in the air, it makes sense also to look for measures that can be taken in sectors other than domestic transport. There is as yet no policy for emissions from wear and tear, including metal particles from tyres and brakes. There are indications that particulates from wear and tear are harmful to health, although the precise health effects are not yet fully known.**

Policies for improving air quality are entering a new phase. In the Netherlands the current policy objectives, which are based on European emission ceilings and limit values for concentrations of pollutants in the air, have almost all been met. The Ministry of Infrastructure and the Environment is currently working on a policy vision for air quality, both in general and for specific sectors. These policies will make health a core issue, as announced by the Government in its memorandum 'Approach to the modernisation of environmental policy' (*Aanpak modernisering milieubeleid*).

In this publication KiM Netherlands Institute for Transport Policy Analysis investigates the relationship between air quality and transport, which is a major emitter of some substances known to be harmful to human health.

The study gives a general picture of the current and future contributions by the transport sector to emissions and ambient concentrations of air pollutants. It also looks at the health effects of these pollutants, what is known about them, and how emissions can be reduced (in a cost-effective way) and to what degree. The 'transport' sector is defined in broad terms: besides road transport, inland waterways, civil aviation and rail, we also include mobile machines used in agriculture and such like. For maritime transport we only looked at the contribution to ambient air concentrations; emissions were not considered because they are not included in the European emission ceilings. The purpose of this study is to provide input to the development of the ministry's policy vision for air quality in general and the implications for the transport sector in particular.

## Air quality policy objectives within reach

The Netherlands is compliant with its four national emission ceilings (NEC) for $SO_x$, $NO_x$, $NH_3$ and non-methane volatile organic compounds (NMVOC) for the period 2010–2019. The ceilings limit the emissions of each pollutant within the Netherlands to a certain number of kilotonnes per year. In addition, there are European standards for the maximum concentration of pollutants in the air, measured in micrograms per cubic metre of air, with limits for daily mean and annual mean values. These ambient air quality standards are met almost everywhere in the Netherlands. In just a few places the standards for $NO_x$ and particulate matter ($PM_{10}$) are exceeded. These exceedances of the $NO_x$ limit values are mainly along busy urban streets in the major cities of the Randstad in the west of the country. Exceedances of the limits for particulate matter are caused mostly by industry and intensive farming.

But the fact that the current legal limits are being complied with does not mean there are no adverse effects on health. In general, there are no thresholds below which a substance can be said to have no effect on human health. The ambient air quality standards and national emission ceilings in the EU were set in a political decision that took account of effects other than health alone, such as economic effects.

It is expected that the ambient air quality standards will soon be back on the agenda in the EU. The European Commission wants to adopt the WHO air quality guidelines, almost all of which are lower than the European limits. The national emission ceilings are already under discussion. In 2013 the European Commission published proposals on lowering the existing NECs for $NO_x$, $NH_3$, $SO_2$ and NMVOC and introducing two new ceilings for $PM_{2.5}$ and $CH_4$ in 2020 and 2030.

## Current contribution by transport

The transport sector is responsible for a relatively large proportion of $NO_x$, NMVOC and particulate matter emissions. It is even the biggest source of $NO_x$ emissions in the Netherlands. Within the transport sector, road traffic is the biggest source of emissions, especially from cars, lorries and vans. For particulate matter, transport accounts for an increasing proportion of emissions as particle size decreases. It is responsible for about 40% of emissions of $PM_{2.5}$ and more than 90% of emissions of ultrafine particles ($PM_{0.1}$). This is an important point, because the health implications of particulates appear to differ according to particle size (see below).

At the moment domestic transport is responsible for about 40% of the average ambient concentration of $NO_2$, but for only about 10% of the average ambient concentrations of $PM_{10}$ and $PM_{2.5}$. Certain fractions of particulate matter, such as metals (from wear and tear of tyres and brakes), soot and ultrafine particles, are highly correlated with road traffic and are found in high concentrations along busy roads. Concentrations fall off rapidly with increasing distance from the road.

## Health effects of transport emissions

Inhaling particulate matter, $NO_2$ and NMVOC – of which transport is a major source – can lead to illness and premature death. These substances can also cause reactions in the air which produce other substances harmful to health, such as ozone and secondary particulate matter. Particulate matter is a mixture of components which can have different health effects. These effects depend largely on the size and chemical properties of the particles. The smaller the particles, the easier it is for them to slip through the body's protection mechanisms and the easier it is for toxic particles in the air to bind to them.

One of the more dangerous fractions of particulate matter is soot, which is a product of combustion processes, although it is probably the compounds which bind to the soot that account for most of the health hazard. Some of the soot fraction consists of ultrafine particulates, which can penetrate deep into the lungs and cause health problems.

There are indications that particulates arising from the wear and tear of vehicle components, especially metals from tyres and brakes, and the ultrafine particulates from traffic are harmful to health as well, although the precise health effects are not known. Ultrafine particulates are so small they can enter the bloodstream through the lungs and so reach other organs. Because the surface area of ultrafine particulates is relatively large compared to their size, their binding capacity to other, toxic substances in the air is greater.

A European study is underway on the health risks of aldehydes, which are associated with the combustion of biofuels. However, the health effects of many other substances in the air have not yet been investigated and there is no literature on the subject.

Little is known about the specific health effects of each means of transport or modality. For example, is it less healthy to breathe in emissions from a moped or from a car? Both emit a mixture of substances. Again, little is known about the degree of exposure to these substances and the resulting health effects. A complicating factor is that there are also big differences between modalities in the mix of particles emitted, depending on the type of fuel, the type of engine, the Euroclass, the age of the vehicle, tuning (for mopeds), etc.

## Expected transport emissions and effect on ambient concentrations

Under current policies, transport emissions of substances for which there are national ceilings are declining. The emission reductions in the transport sector are generally larger than in other sectors that fall under the national emission ceilings. Emissions of $SO_2$ from transport are already low. Most of the other reductions are in road traffic emissions, driven by the European emission standards for vehicles. These standards apply to new vehicles and so they will spread slowly throughout the whole car fleet as the older vehicles are replaced. Under these European standards all new diesel vehicles (cars, lorries and vans) are fitted with highly efficient particulate filters. By 2030 the concentration of $PM_{2.5}$ is expected to approach the level of the WHO air quality guidelines, which are half those of European standards – at least as long as the particulate filters are not removed from the cars, which is something the national vehicle inspection test does not see to. The new Euro VI standard reduces $NO_x$ emissions from lorries to a tenth of what they were. For passenger cars and vans the Euro 6 standard is less effective at reducing $NO_x$ emissions, because actual emissions on the road are very different from the standards. A new test procedure will be introduced in a European policy initiative, although it is still uncertain what its effect will be. The proportion of diesel cars in the Dutch fleet is relatively limited compared with neighbouring countries.

The most recent Euro standards for road vehicles also contain a particle number (PN) standard for the number of particles emitted. This is aimed primarily at ultrafine particles, because these make up the biggest fraction of emitted particulate matter. A major component of ultrafine particles is soot. The PN standard can be met by using an advanced particulate filter. Its introduction is expected to reduce the ambient soot concentrations in the Netherlands by half over the coming decade. Road traffic will then contribute just as much to ambient soot levels in urban areas as domestic wood burning stoves.

Road traffic emissions from wear and tear are not tackled by the current standards and are expected to increase slightly in line with the growth in road traffic. If the current trend continues, in a few years wear and tear will be a bigger source of primary particulate matter than the combustion processes in vehicle engines.

The European emission limits for mopeds are being lowered in 2017. It is expected that two-stroke mopeds, which emit relatively high levels of volatile organic compounds, will not be able to meet this standard. Four-stroke mopeds, which can in principle meet the new standard, will become much cleaner under the tighter emission standard than the current generation of mopeds. Emissions from mopeds of particulate matter and ultrafine particles in particular will fall sharply. At the moment mopeds account for a few per cent of the vehicular particulate matter and $NO_x$ concentrations in urban areas.

## Possible reduction measures in the transport sector

The technologies available to meet the current Euro 6 and Euro VI standards (for cars, vans, lorries and buses) are very effective at cutting down traffic emissions of $NO_x$ and particulate matter, including ultrafine particles. The key technologies are particulate filters and SCR catalytic converters. There are no signs of any new technologies that can bring about significant reduction in emissions beyond the Euro 6 and Euro VI standards – if they are even needed at all, given the considerable effectiveness of the currently available measures. Emission reduction is mainly a question of properly applying best available techniques and continuing to do so. This could be done by improving the testing frequency of cars to keep actual emissions in step with standards, inspecting the disposal of particulate filters and ensuring a regular supply of the special liquid the SCR catalytic converters need to operate. The European standards on mopeds will accelerate the shift from two-stroke to four-stroke engines and electric mopeds.

The cheapest remaining emission-reducing technologies can be found in the inland shipping sector – where SCR is little used – and maritime shipping. Reducing shipping emissions will affect ambient air concentrations on land.

There are also other ways to restrict emissions of pollutants to the air than through engine technology, such more efficient transport, logistics and using cars less.


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It is uncertain whether the mobility section of the SER Energy Agreement (signed by government and a wide variety of public and private sector organisations) can bring about emissions reductions in the transport sector not only in $CO_2$, but also in $NO_x$ and $PM_{10}$. This depends a great deal on how the $CO_2$ target is met. Using alternative power systems, as in electric vehicles for example, can deliver substantial reductions in $NO_x$ and particulate matter as high as 50%. Using biofuels will have little or no effect on $NO_x$ and particulate matter emissions. Any substantial effects on air quality resulting from the SER Energy Agreement, such as large proportion of alternative vehicles, are not expected before 2030.

## Policy leverage points and new indicators

### Emission ceilings versus ambient air concentrations

The points for effective policy leverage to meet national emission ceilings differ in a number of respects from those to meet concentration limit values. Reductions in the emissions in the Netherlands can sometimes have a limited effect on the concentration of the pollutant in the air, because this is also affected by foreign sources and the secondary formation of compounds in the air.

In the Netherlands the best prospects for meeting the NECs for 2030 as proposed by the European Commission are emission reductions in other sectors than the transport sector, because this is where cheaper measures can still be found. An exception is the use of SCR catalytic converters in inland shipping. This is relatively cheap and can make a big impact, and it is the only transport measure included in the recent cost–benefit analysis (CBA) of the proposed emission ceilings by PBL Netherlands Environmental Assessment Agency. The outcome of the CBA was positive (Smeets et al., 2015). If maritime emissions counted towards national ceilings, as proposed by the European Commission, cost-effective measures could be found here, too.

The biggest social benefits in the CBA are from reductions achieved outside the Netherlands, in connection with the level of the emission ceilings in these countries. This type of air quality policy, based on emission ceilings per EU member state, is cost-effective for the Netherlands because it is European in scope; reducing emissions in the Netherlands alone may not be cost-effective.

The most effective way to lower ambient concentrations of particulate matter in the Netherlands is considered to be by reducing emissions of $NO_x$ and $NH_3$ (in the Netherlands and abroad). This is even more effective than direct reductions in emitted particulate matter. This effect is not restricted to transport. $NO_x$ and $NH_3$ cause secondary particulate matter, which becomes a background concentration of particulate matter in the Netherlands. Secondary particulate matter currently makes up about a third of the total mass of particulates in the air.

### Geographical scale of policy measures

The European exhaust emission standards apply to emissions from *new* vehicles in Europe and so they will only slowly be adopted throughout the total European car fleet. Direct effects on the *existing* fleet are best achieved through national or local policies, such as tax policy, grants, environmental zones, etc.

Local emission reduction measures (for example, traffic diversion or local speed restrictions) have little effect on the ambient air concentrations of $PM_{10}$ and $PM_{2.5}$. They can have a bigger effect on the concentration of ultrafine particles ($PM_{0.1}$) and soot along the roads concerned, because they are more closely correlated with the traffic on those roads. The health gains of this type of measures accrue mainly to people living in the direct neighbourhood of the roads.

### New substances or fractions

Particulates from wear and tear of road vehicles, including metal particles from tyres and brakes, are not addressed by the existing exhaust emission standards. They do count towards the national emission ceiling, though. The volume of emissions depends on traffic volumes and is slowly rising. The health effects are not yet fully known. What is needed is a good problem definition of emissions from wear and tear that includes both the scale of the emissions and their health effects. Little thought has yet been given to ways to reduce emissions from wear and tear.

There are references in the literature that argue for specific policies for soot. The new European PN standards do just that.

We found no new substances described in the literature that are not covered by current legislation and urgently need regulation – with the proviso that the health effects of many of the substances in the air have never been investigated at all. The WHO considers current knowledge about ultrafine particles to be insufficient to determine a safe concentration value. The growing use of biofuels has prompted an ongoing European study into aldehydes, which are NMVOCs with specific health effects.

Neither did we find any arguments in the literature to justify revoking some of the current regulations. The WHO argues explicitly for maintaining the ambient air concentration standards for both $PM_{10}$ and $PM_{2.5}$, because the possible health effects of the coarser and finer fractions of particulates have different properties.