No Smoking, Please
The Road to Cleaner Trucks and Buses

Chances are you’ve seen—or smelled—a diesel truck or bus belching smoke. Perhaps you’ve been stuck in traffic behind an odiferous semi-truck, watched children board a school bus with exhaust that doesn’t seem very magical, or been “coal rolled” with a plume of black smoke from a jacked-up pickup truck while walking down the sidewalk.
Perhaps you’ve also noticed a decrease in these “smokers” in recent years; if so, this is no accident, but the result of cleaner trucks that have evolved over the past 20 years in response to tighter emission standards. This article summarizes the contribution of diesel trucks to air pollution and health problems, milestones on the road to cleaner trucks (along with some bumps in the road), and what the future might hold.

**Truck Pollution and Health**

Air pollution from cars and trucks has been linked to premature death and serious illnesses, including respiratory disease, stroke, heart disease, and cancer. The World Health Organization estimates that urban air pollution causes more than one million deaths per year worldwide, and studies have suggested possible links between air pollution and other health problems, including developmental disabilities, Alzheimer’s disease, diabetes, and birth defects.

These health problems are caused by different compounds in the air, including ozone, formed from volatile organic compounds (VOCs) and oxides of nitrogen (NOx); fine particulate matter (PM-2.5), including black soot, directly emitted or formed secondarily in the atmosphere; toxic compounds such as benzene and acetaldehyde; and carbon monoxide (CO).

In the United States, motor vehicles are among the largest contributors of VOC, NOx, CO, and toxics, and contribute a significant share of PM-2.5. Concern with transport-related pollution is increased because we tend to live, work, and play close to this pollution source; nearly 60 million (or one-fifth) of people in the United States live near a major roadway, with many more spending their work or school day near a major road. Recent studies have confirmed that the concentration of pollutants is much higher within 300 meters of major roadways, and that those living within this distance from roadways suffer higher rates of illness and premature death.

**The Road to Cleaner Trucks… with Some Bumps**

Emission limits for cars were first introduced in the late 1960s, and have since been lowered many times over. Though diesel trucks are by far the largest source of transport-related PM-2.5, and contribute the majority of vehicle NOx emissions, emission limits for trucks and buses weren’t introduced in the United States until the mid-1980s. Emission limits for NOx and PM from diesel trucks were first introduced in the United States for engines built in 1985, with subsequent reductions in emission limits through the 1990s and 2000s (see Figure 1). These limits (along with a desire for improved fuel economy) led to the adoption of electronic engine controls in the 1990s, augmented by emission control systems such as Exhaust Gas Recirculation (EGR), which routes a portion of exhaust gas back into engine cylinders to inhibit the formation of NOx.

While the evolution of emission limits and technology through the 1990s provided a roadmap toward cleaner trucks, bumps in the road soon emerged. Field research showed that on whole, NOx emissions from diesel trucks built in the 1990s were not coming down as expected. Further investigation revealed that loopholes in emissions regulations were being exploited by diesel engine manufacturers to improve over-the-road fuel economy at the expense of NOx emissions, using the engine’s computer to detect when the truck was operating outside of compliance test conditions (the same issue that has recently emerged for some diesel-fueled passenger cars). When this was uncovered, offending trucks required reprogramming, and compliance procedures were tightened to require checks under a broader range of operation.

**Exhaust Aftertreatment: The Game-Changer**

In the United States, stringent PM and NOx limits for engines built in 2007 and 2010, respectively, were 90 percent lower than previous limits, leading to exhaust aftertreatment systems on most new diesel trucks and buses (see Figure 2). Diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs) have been used to reduce PM. Properly functioning DPFs filter out nearly all elemental carbon-based PM emissions (soot). Figure 3 shows a filter placed at the end of an exhaust pipe without a DPF, and with a DPF (imagine your lungs as this filter!).

Selective Catalytic Reduction (SCR) systems are used to control NOx. These units work similarly to catalytic converters on cars, but require the injection of a reductant (typically ammonia or...
urea) to convert NOx in the raw exhaust stream to nitrogen, water, and carbon dioxide. DPF and SCR systems require diesel fuel with very low sulfur content (e.g., 15 parts per million, ppm) introduced in the United States concurrently with the new emission limits. Europe has adopted “Euro VI” emission limits with similar stringency, along with low sulfur fuel. High sulfur levels in diesel fuel have delayed implementation of these limits in other countries, including China and Mexico.

Due to these standards, the U.S. Environmental Protection Agency (EPA) projects that diesel PM and NOx emissions in the United States will drop substantially in the coming decades (see Figure 4). Drops in gasoline cars and light trucks are also projected from concurrent regulations. PM and NOx from all vehicles are projected to drop nearly 90 percent between 2000 and 2030, despite growth in miles travelled.

These projections assume that exhaust aftertreatment devices are properly functioning and effective under all conditions, however. In reality, DPFs require regular regeneration to burn off accumulated soot, and are vulnerable to clogging or cracking. Recent studies have also shown that some SCR systems lose effectiveness during prolonged idle or low speed operation (typical in urban areas), leading to high NOx emissions. It will be essential to track the emissions of trucks equipped with SCR and DPFs in the field, using newer research methods such as on-board emissions measurement systems, roadside remote sensing and portable field labs, to ensure that projected reductions are indeed becoming reality.

What about Old Trucks?
While new emission limits are the most direct road to clean trucks, it is a long road, because older trucks can remain in use for decades until being replaced. Since older trucks are the dirtiest, a concerted effort has been made to retrofit old trucks with DPFs, rebuild engines, or replace older trucks with newer trucks, often funded with federal grants through the Diesel Emission Reduction Act (DERA). In California, the reduction of emissions from older trucks is now required by law, to ensure a timetable for getting dirty trucks off the road.

How Low Can We Go?
Though trucks meeting the latest emissions limits are still entering the fleet, further advances are being pursued to achieve clean air goals. California is currently considering new diesel emission limits that are 90 percent lower than the U.S. 2010 NOx limits. Recent greenhouse gas and fuel economy requirements in the United States are expected to result in higher engine efficiencies, lower rolling-resistance tires, and aerodynamic improvements that will lower NOx emissions as well. Advanced technologies and alternative fuels are also playing an important role. Compressed natural gas (CNG) and hybrid transit buses are now commonplace in many major cities, and these same technologies are being applied to delivery trucks and other specialty truck applications.
Conclusions

Stringent emissions limits and major advances in technology have soot-belching trucks and buses on their way to becoming relics of the past, although the wheels are not in motion for this worldwide. While the technology now exists to reduce diesel truck emissions several-fold from pre-control levels, barriers to implementation—be they political, economic, or technical—are slowing progress in some countries. Fuel is one issue; without implementation of clean fuel, truck emissions will remain high, along with serious health effects linked to air pollution in general and diesel exhaust in particular.

Even for countries with clean fuel and trucks in place, continued diligence is needed to ensure that emission reductions projected on paper are realized in the air. Advances in emission measurement technology can be employed to assess the emissions of trucks “in the wild,” to judge whether clean trucks are remaining clean over time and under all operating conditions. Past experience has shown that without this diligence, the road to clean trucks may encounter some detours.

Figure 4. U.S. NOx and PM emissions from cars and trucks 1990–2040.

Source: U.S. Environmental Protection Agency (EPA).

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References