Main Pollutants emitted by vehicle Engines

Main pollutants:	**How is it formed:**	**Environmental problems:**
Hydrocarbons (HC)	Formed when fuel is not fully burnt.	Contributes to ground-level ozone when it reacts with NO_X and sunlight. Cancer.[i] Respiratory problems.
Carbon Monoxide (CO)	Formed when substances containing carbon do not have access to enough air.	Global warming.[ii] Ground ozone, which can damage plants and crops, and cause respiratory problems, even death.
Nitrogen Oxide (NO_X)	Formed when fuels are burnt at high temperatures.	Acid rain. Oxygen deficit. Haze air pollution.[iii] Contributes to formation of particles and smog. These can then cause health problems.
Particles (PM_{10})	Formed from the burning of fossil fuels.	Can cause respiratory disease and premature death.[iv] Reduces visibility. Turns water in lakes and ponds acidic. Can damage crops.[v]

There are three different types of vehicle engine: conventional, lean-burn and diesel. They all produce different types of exhaust emissions because of the ratio of air to fuel that they use. Conventional engines use high levels of fuel and so produce more nitrogen oxides. Lean-burn engines use high amounts of air and so produce more hydrocarbons. Diesel engines are like lean-burn engines, but produce high levels of particles and smoke.[vi]

Acid rain

NO_X emissions are oxidised in the atmosphere to form NO_2. This then reacts with OH radicals to form HNO_3, or nitric acid. This then falls to Earth as acid rain.
This can be shown as the reactions below.

$$2NO + O_2 \longrightarrow 2NO_2$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$NO_2 + OH \longrightarrow HNO_3$$ [vii]

Heterogeneous Catalyst

A heterogeneous catalyst means that the reactant is in a different physical state to the catalyst. This generally means a solid catalyst and a mixture of gases or liquids as the reactants. A solid catalyst means that the reaction takes place on its surface. Reactants are adsorbed onto the surface, and their bonds weaken and break, allowing new bonds to form, creating the products. Bonds to the catalyst weaken and the product molecules are released. The solid catalyst is usually divided or in a wire mesh to create a large surface area for contact with the reactants.[viii]

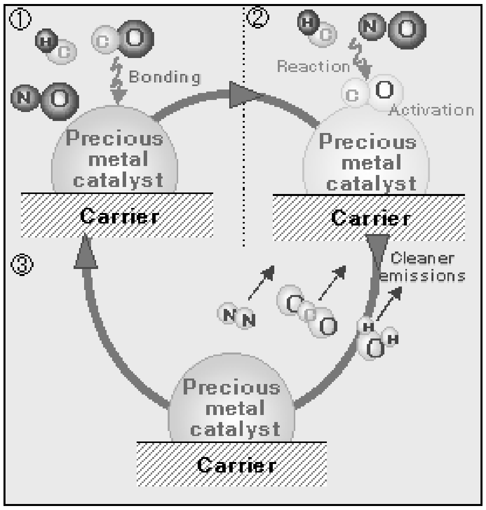

Figure 1: Reactions that occur when using a heterogeneous catalyst.[ix]

<u>Noxer blocks</u>

Titanium dioxide crystals catalyses the oxidation reaction to remove NO_X because it absorbs ultraviolet radiation, which excites its electrons to a higher energy level. Reactions can then take place on the surface of the crystals because of the extra energy. Water and oxygen react to form hydrogen, a superoxide ion and a hydroxyl radical.

$O_2 + e^- \longrightarrow O_2^-$

$H_2O \longrightarrow H^+ + OH + e^-$

<u>Overall Reaction</u>

$H_2O + O_2 \longrightarrow H^+ + O_2^- + OH$

The hydroxyl radical then reacts with nitrogen dioxide and oxidises it to nitrate ions. The superoxide ion reacts with nitrogen monoxide to form nitrate ions.

$NO_2 + OH \longrightarrow H^+ + NO_3^-$

$NO + O_2^- \longrightarrow NO_3^-$

These nitrates are then either washed away or absorbed by the blocks to form stable compounds.
The crystals also catalyse the reaction because the surface of the block holds together the reactants. This increases the concentration of the reactants.

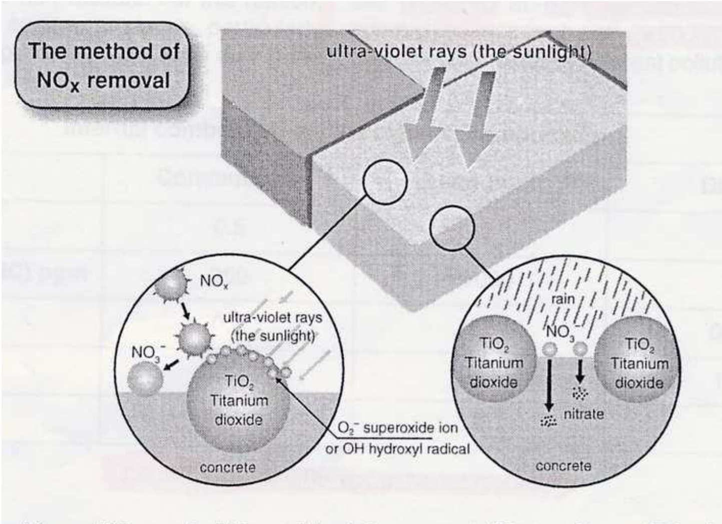

Figure 2: NO$_X$ removal by titanium oxide crystals.[x]

Three-way Catalytic Converters

A three-way catalytic converter oxidises carbon monoxide and hydrocarbons, and reduces the levels of nitrogen oxides. It does this by creating the right conditions for reactions of these emissions to occur.
The air to fuel ratio must be carefully controlled as oxygen is needed for the reaction of carbon monoxide and hydrocarbons. Oxygen sensors are fitted in engines with a three-way catalyst.

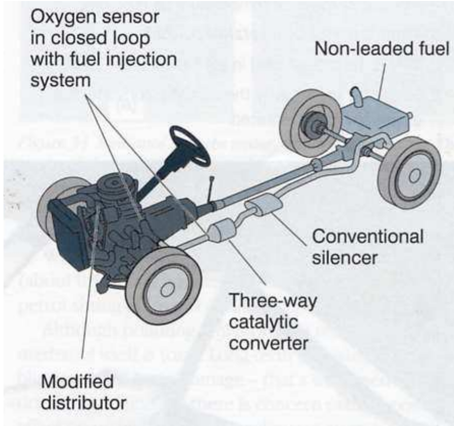

Figure 3: The three-way catalyst system.[xi]

Three-way catalysts are designed to produce more desirable reactions and less undesirable reactions. Desirable reactions reduce the harmful emissions from the car exhaust. Carbon monoxide and hydrocarbons react with oxygen to produce carbon dioxide and water, and nitrogen oxides react with carbon monoxide to produce carbon dioxide and nitrogen. The products are already present in the Earth's atmosphere.

$2CO + O_2 \longrightarrow 2CO_2$

$C_7H_{16} + 11O_2 \longrightarrow 8H_2O + 7CO_2$

$2CO + 2NO \longrightarrow 2CO_2 + N_2$ [xii]

Three-way catalytic converters contain the stoichiometric fuel mixture. This means that the catalysts have the right amount of oxygen to combust the fuel and react with the carbon monoxide and hydrocarbons.

Three-way catalysts also contain ceria, which stores oxygen when the mixture is lean, and releases it when the mixture is rich. This gives optimum conversion of pollutants because as the carbon monoxide and hydrocarbons are absorbed onto the catalyst's surface, the oxygen stored by the ceria oxidises them even if there is not enough oxygen in the air to fuel ratio.[xiii]

The future

Scientists still have problems that need to be solved to reduce harmful vehicle emissions. One problem that needs to be addressed is how to prevent harmful exhaust emissions when the catalyst is still warming up. There are several ways that this could be dealt with, including operating the catalysts at lower temperatures and also heating the catalyst before the engine is started.[xiv]

Scientists also need to develop a system that is able to reduce nitrogen oxide emissions from diesel engines. There are several ideas on how to go about this, including using ammonia in the exhaust, but nothing has yet been developed.

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[i] http://www.nutramed.com/environment/carsepa.htm; Stephen Gislason MD; Date looked at: 30th April 2007
[ii] http://www.environment-agency.gov.uk/yourenv/eff/1190084/air/1158715/1159675/?lang=_e; Jason Dinsdale 2007; Date looked at: 25th April 2007
[iii] Nitrogen Oxides Fact sheet; Environmental Defense; December 2002; http://www.environmentaldefense.org/documents/2551_FactSheet_NOx.pdf; Date looked at: 25th April 2007
[iv] http://www.environment-agency.gov.uk/yourenv/eff/1190084/air/1158715/1163071/?lang=_e; Jason Dinsdale; Date looked at: 30th April 2007
[v] http://www.epa.gov/air/particlepollution/health.html; March 2007; Date looked at: 3rd May 2007
[vi] Chemistry (Salters) Open-book Paper, Page 7; Article 2: Emission Control; Brian Harrison; September 2000
[vii] Chemistry (Salters) Open-book Paper, Page 3; Article 1: Paved with Titanium; Stephanie Makins; 2002
[viii] Salters Advanced Chemistry; Chemical Ideas (Second Edition); Page 240; Heinemann 2000
[ix] http://vpd.ms.northwestern.edu/memberpages.asp?url=members/feng/Research%20Background.htm; Date looked at: 30th April 2007
[x] Chemistry (Salters) Open-book Paper, Page 5; Article 1: Paved with Titanium; Stephanie Makins; 2002
[xi] Salters Advanced Chemistry; Chemical Storylines (Second Edition); Page 37; Heinemann 2000
[xii] Chemistry (Salters) Open-book Paper, Page 8; Article 2: Emission Control; Brian Harrison; September 2000
[xiii] Chemistry (Salters) Open-book Paper, Page 8-9; Article 2: Emission Control; Brian Harrison; September 2000
[xiv] Chemistry (Salters) Open-book Paper, Page 9; Article 2: Emission Control; Brian Harrison; September 2000