CLEANER MOTORCYCLES

Promoting the use of four-stroke engines

Photo: Ernst Tobish

KJAER GROUP

Partnership for Clean Fuels and Vehicles

UNEP

Photo : UNEP

INTRODUCTION

Reliable, affordable and safe transport is a prerequisite for development. However, transport is also a major source of air pollution and contributes to greenhouse gas emissions that cause climate change.

Motorcycles and three-wheelers offer quick, affordable and flexible transport for many people around the globe. However, the less sophisticated engine technology of motorcycles and the lack of strict emission regulations in many parts of the world have resulted in high emissions of pollutants by motorcycles. In many cities in developing countries they are among the main sources of urban air pollution.

The main pollutants in motorcycle exhaust fumes – depending on several factors, such as fuel used - are particulate matter (PM), hydrocarbons (HC), volatile organic compounds (VOCs), nitrogen oxides (NOx) and lead (Pb). In addition, emissions of carbon dioxide (CO_2) are contributing to climate change.

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Together, these pollutants seriously affect human health and the environment in the following ways.

ENVIRONMENT AND HEALTH ISSUES

> Respiratory symptoms

Coughs, eye, nose and throat irritation, allergies, reduced lung capacity and fatigue are all linked to high levels of air pollution. Elderly people and people with asthma are especially vulnerable and at risk of premature death. Children suffer from an increased risk of acute respiratory infections.

> Cardiovascular diseases (diseases of the heart and lung systems)

Emissions of particulate matter (PM) – very small particles emitted into the air – increase the risk of cardiovascular diseases (diseases of the heart and lung systems), resulting in heart attacks and premature deaths. The elderly and those with a heart condition are at greatest risk.

> Inhalation of small particles and lead

In some countries leaded petrol is still in use – and here vehicles emit small lead particles that, when inhaled, have severe health impacts. Lead damages

the central nervous system. In particular, children exposed to lead suffer from learning disabilities. Inhalation of certain small particles can also cause cancer.

> **Global and regional impacts affecting our living conditions**
Emissions of carbon dioxide (CO_2) are causing the climate to get warmer and more unstable (climate change), and emissions of sulphur are also causing damage to plants and buildings.

THE EFFECTS OF AIR POLLUTION TODAY

The World Health Organisation (WHO 2002) estimates that 800,000 deaths are attributable to air pollution every year. Air pollution cost nations billions of dollars in medical bills and loss of productivity. Transport is a major source of air pollution, especially in urban areas.

> In **developing countries** approximately 13% of the burden of disease is related to air pollution. In **developed countries** an estimated 2-6% of the overall burden of disease is related to air pollution[1].

> In **Dhaka** over 10,000 premature deaths per year have been attributed to air pollution at a cost of 3-4% of gross domestic product (GDP). In **Mexico City** some 4,000 premature deaths per year are linked to high particulate matter concentrations in the air[2].

> In the **EU** the average life expectancy is reduced by 10 months due to air pollution from transport and the related cost is estimated to be 1.1 % of GDP[3].

[1] WHO (2002) The World Health Report 2002
[2] Azad et al. (2003) An Economic Evaluation of Air Pollution in Dhaka City, Proceedings: International Conference on Chemical Engineering Dhaka, Bangladesh. p.83-87
[3] EEA (2005) Environment and Health. Report no 10/2005

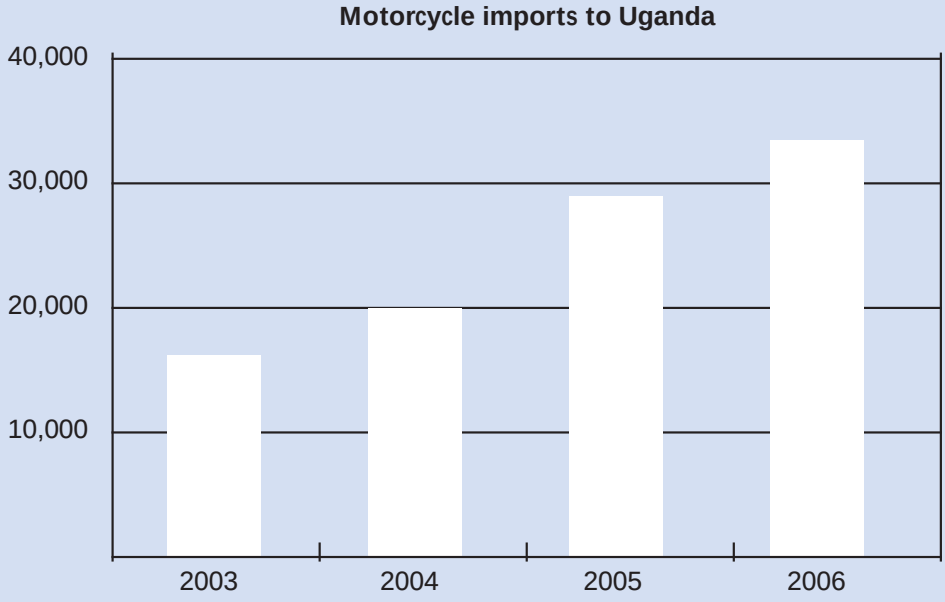

Photo: Ernst Tobish

Fast growing cities in developing and transition countries, in particular, face serious air pollution problems due to rapidly increasing vehicle usage, congestion, dirty fuels, low technical standards, and a lack of inspection and maintenance. In many of these cities, motorcycles play a key role and can even constitute the prime source of urban air pollution through harmful emissions of particulate matter, nitrogen oxides (NOx), and volatile organic compounds (VOCs).

Motorcycles and three-wheelers around the world

Motorcycles and three-wheelers make up a substantial share of the total transport capacity in many developing countries. This is especially so in Asia, where motorcycles and three-wheelers constitute 50-80% of all vehicles in most major cities, so called "motorcycle cities".

However, the use of motorcycles is rapidly increasing in other parts of the world. In Africa and Latin America, motorcycles are becoming increasingly popular as an affordable means of transport. The figure below shows the example of Uganda, where motorcycle imports have tripled over the past three years. By comparison, in 2006 Uganda imported three times as many motorcycles as personal cars.



Although 85 percent of motorcycles are the more polluting two-stroke type, four-stroke motorcycles are becoming increasingly common. In Europe and the USA, motorcycles represent only a minor percentage of total transport and three-wheelers are practically non-existent.

HOW MOTORCYCLE ENGINES INFLUENCE EMISSIONS

Motorcycles can have either two-stroke or four-stroke engines. The difference between a two-stroke and a four-stroke engine is the number of "strokes[4]" the piston makes for each ignition. This principal design difference has benefits as well as disadvantages.

ADVANTAGES OF TWO-STROKE MOTORCYCLE ENGINES

Two-stroke engines have traditionally been used in motorcycles due to lower engine costs and smaller size compared to a four-stroke engine.

> Smaller size

The two-stroke design, with a power stroke per piston for every engine revolution instead of every second revolution, enables a high power-to-weight & volume ratio that suits smaller engine requirements such as mopeds, small motorcycles, lawn mowers and chainsaws.

> Less costly to buy and mechanical simplicity

The design of a two-stroke engine is relatively simple, with fewer moving parts compared to a four-stroke engine. This makes the two-stroke engine less expensive to manufacture and repair. The price difference between two-stroke and four-stroke engines differs locally, but is usually small (and is decreasing).

DISADVANTAGES OF TWO-STROKE MOTORCYCLE ENGINES

> The total cost of owning a two-stroke engine is usually higher due to high fuel costs

Even though a two-stroke engine is often cheaper to buy than a four-stroke, the total cost (lifecycle cost) of buying, fuelling and maintaining a two-stroke motorcycle is usually higher compared to a four-stroke. The main reason is the lower fuel consumption of a four-stroke engine and the cost of adding lubricating oil to the petrol for a two-stroke engine.

Due to the specifics of the two-stroke engine design, some of the fuel/airmixture escapes directly out of the exhaust. This results in 10-15% higher fuel consumption with a two-stroke engine compared to a four-stroke, and consequently 10-15% higher emissions of carbon dioxide (CO_2) as well.

[4] A stroke is a linear movement of the piston

Two–stroke engines also need more maintenance. They typically need to be overhauled every 30,000 km and decarbonised (due to high emissions of hydrocarbons) every 6,000 km. However, the maintenance of a four-stroke engine can be more complicated due to it having more moving parts such as valves.

> Two-stroke engines emit more pollution

Two-stroke engines emit more volatile organic compounds (VOCs), hydrocarbons (HCs) and particulate matter (PM) compared to four-stroke engines. A mixture of exhaust gases, unburned fuel and burned lubricating oil - combusted together with the fuel - cause high levels of harmful emissions. However, two-stroke engines emit less nitrogen oxides (NOx) than four-stroke engines.

In practice, two-stroke engine emissions are often several times higher than those of a similar four-stroke engine.

This is caused by using too much or the wrong type of lubricating oil and poor maintenance. Overdosing or using the wrong type of lubricating oil exacerbates emissions, increases engine wear (which in itself increases emissions), and poisons any catalyst. In developing countries many motorcycles are poorly maintained and emissions from two-stroke engines in particular can increase significantly in such cases.

> Use of cleaner technologies – catalysts - is more difficult

Two-stroke engines can use an oxidation catalyst. This is a device installed in the tailpipe that can clean the exhaust. However, to use this technology, the right fuel quality needs to be available, i.e. unleaded petrol with a sulphur content of 300 parts per million or less. Two-stroke engines have generally high exhaust temperatures that will sinter and deactivate an oxidation catalyst after some time. A catalyst in normal two-stroke engines typically needs to be replaced every 15,000-30,000 km.

Photo: Riders for Health

Photo: Richard Stanley Make Roads Safe Campaign

The need to reduce emissions from motorcycles has forced the introduction of several technologies previously only used in passenger cars. Modern two-stroke engines utilising the latest technologies described below can compete with standard four-stroke engines on environmental performance while maintaining some of their specific advantages, especially the smaller engines (<125 cc). However, as new technologies are adopted to enable modern two-stroke engines to meet stricter environmental requirements, their cost becomes comparable to that of a four-stroke engine.

In the long term, the cleanest motorcycle engines are four-stroke engines equipped with a three-way catalyst.

Advanced two-stroke direct injected engines equipped with catalyst can however be comparably clean and competitive in the smaller engine segment (<125 cc).

> Fuel injection systems

The use of electronic direct fuel injection systems, rather than carburettors, is a crucial step towards reducing motorcycle engine emissions. Both two-stroke and four-stroke engines benefit from fuel injection systems. The introduction of fuel injection systems will also reduce engine wear and increase catalyst durability.

> Exhaust emission control technologies

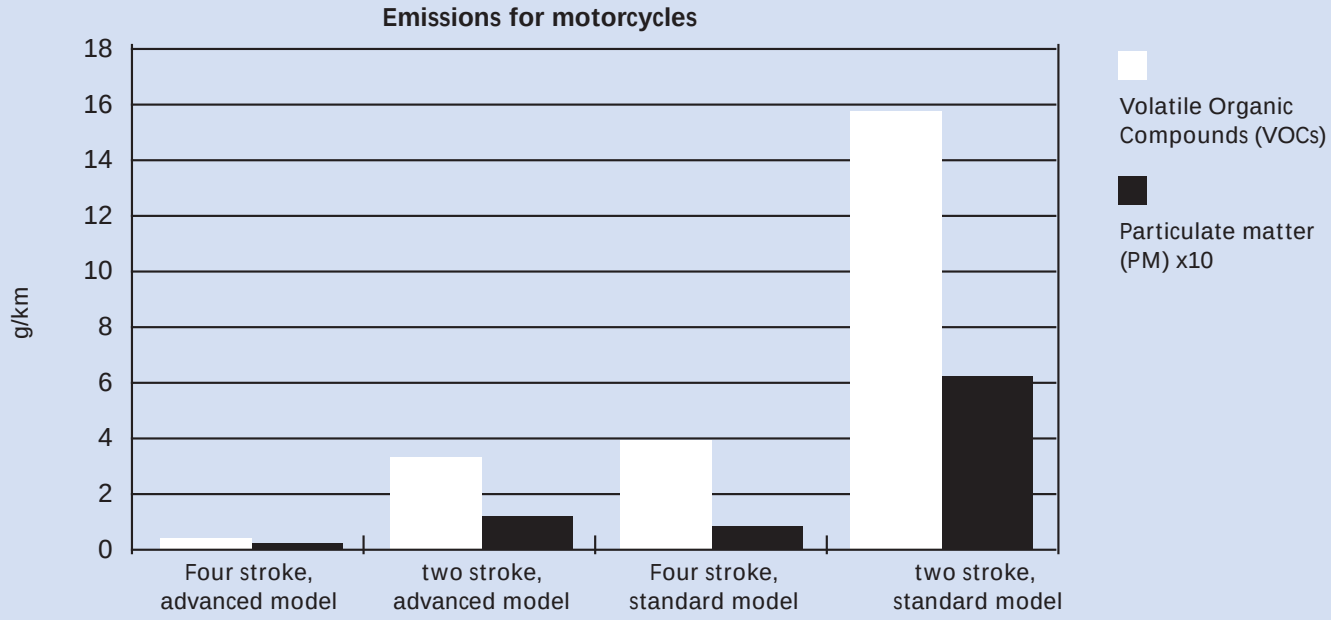
Some countries with strict emission regulations (such as the US , the EU, India and Taiwan) have made the installation of oxidation catalysts mandatory for motorcycles. Oxidation catalysts on two-stroke engines reduce pollutants by 50-80%. Another technical improvement is secondary air injection (SAI), which helps to reduce emissions by up to 25%. Four-stroke engines can be equipped with even cleaner technologies: three-way catalysts that reduce emissions by 90% or more.

> Better and automatic use of lubricating oil for two-stroke engines

Automatic injection of lubricating oil into fuel in two-stroke engines avoids overdosing and reduces emissions substantially. Most countries with strict regulations have made this technology mandatory (USA, EU, Japan and parts of East Asia).

The use of synthetic lubrication oil instead of mineral lubricating oil is also a crucial step towards reducing emissions from two-stroke motorcycle engines. Synthetic lubricating oil burns easier and thus results in fewer pollutants in emissions. Synthetic oil costs more than mineral oil, but given the reduction in emissions achieved this is still a cost efficient way to reduce emissions.

The figure below shows the differences in emissions between standard two-stroke engines and four-stroke engines with a standard design and incorporating the latest clean technologies.

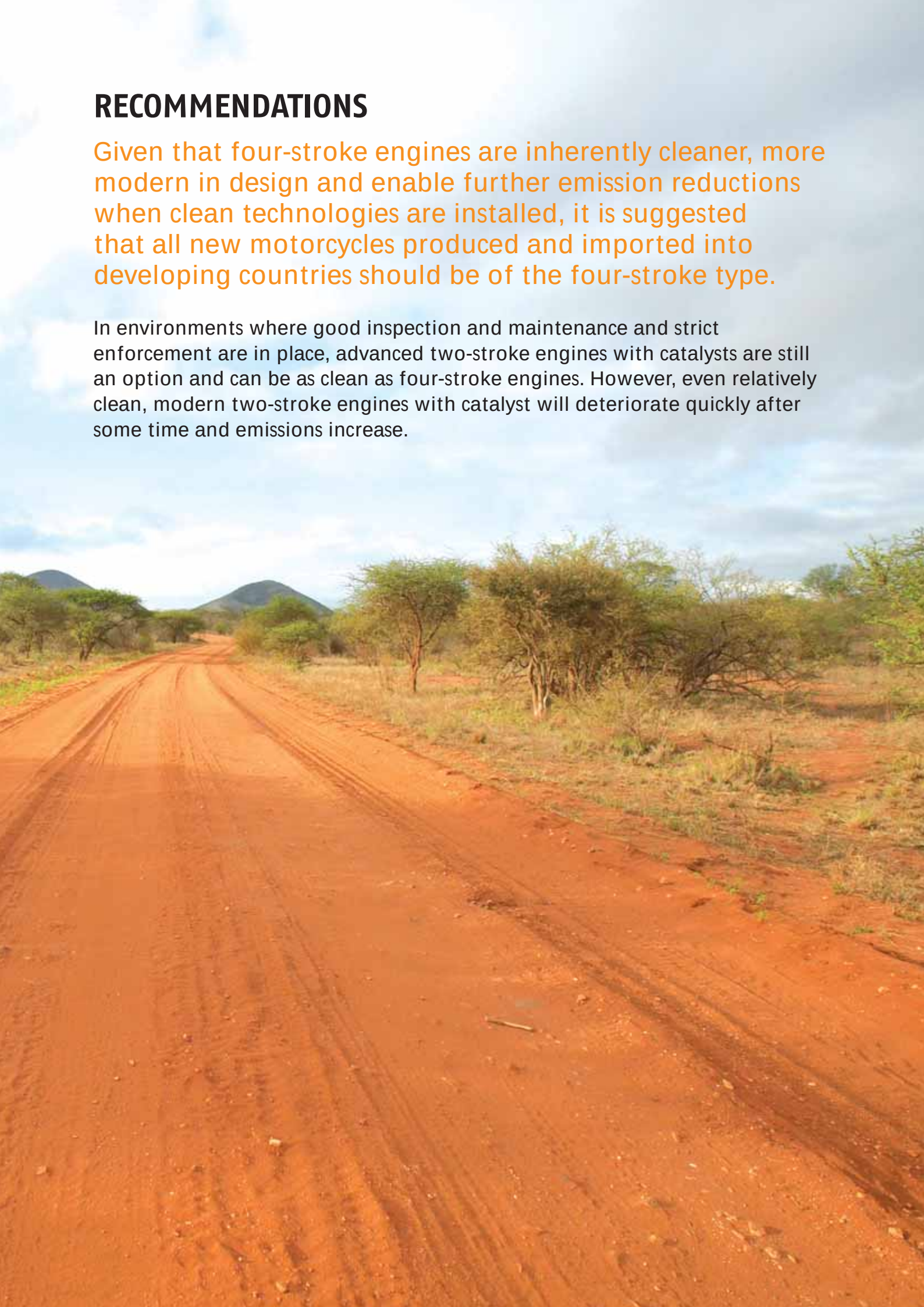


Emissions from standard two-stroke and four-stroke motorcycles compared with advanced models. The advanced models in the figure use fuel injection systems and catalysts. Standard models use carburettor and no catalyst Note: Based on real life Nairobi driving patterns and IVE model 1.1.1a by Jim Lentz (see http://www.gssr.net)

RECOMMENDATIONS

Given that four-stroke engines are inherently cleaner, more modern in design and enable further emission reductions when clean technologies are installed, it is suggested that all new motorcycles produced and imported into developing countries should be of the four-stroke type.

In environments where good inspection and maintenance and strict enforcement are in place, advanced two-stroke engines with catalysts are still an option and can be as clean as four-stroke engines. However, even relatively clean, modern two-stroke engines with catalyst will deteriorate quickly after some time and emissions increase.



The Partnership for Clean Fuels and Vehicles (PCFV) is the leading global initiative promoting better urban air quality through the use of cleaner fuels and vehicles. Established at the World Summit for Sustainable Development in 2002, as of 1 January 2006 it has over 90 member organisations including governments, international organisations, industry groups, and non-governmental organisations involved in efforts to eliminate leaded gasoline worldwide and promote low sulphur in fuels concurrently with the introduction of cleaner vehicles and vehicle technology.

Partnership activities focus on building consensus between all sectors and facilitating the transfer of knowledge and technology on cleaner fuels and vehicles from developed to developing countries.

The PCFV, whose Clearing-House is based at the United Nations Environment Programme (UNEP) headquarters in Nairobi, Kenya, provides technical, networking and financial support for regional, national and local activities promoting cleaner fuels and vehicles. For more information on the PCFV and its work, please visit www.unep.org/pcfv.

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