HEALTH AND ENVIRONMENTAL BENEFITS OF LOW SULFUR FUELS

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July 22, 2008

Introduction

Definition

- Pollution:
  - Is the undesirable change in the physical, chemical or biological characteristics of air, water, and soil that may;
    - harmfully affect life or
    - create a potential health hazard of any living organism

- Pollutant:
  - Any substance which causes pollution
  - Any solid, liquid or gaseous substances present in such concentrations as may be or tend to be injuries to health and the environment

- Air pollution:
  - Is the presence of pollutants in air in sufficient quantity and duration to cause injury to human health and the environment

Introduction cont'd

- Air pollution, both indoor and outdoors, is the major health and environmental problem both in developed and developing countries

- vehicle pollution is distinguished from other sources of air pollution in that emissions are released in close proximity to those exposed
  - For example, vehicles are 300 times more effective in contributing to human exposure than emissions from 200-meter smokestack (Katherine *et al*., 2006)

- Urban areas and surroundings are most seriously affected by vehicle pollution:
  - With human health impacts,
  - Decreased visibility and
  - Material and environmental damage

Emissions are released in close proximity (UNEP & PCFV----)

Urban air quality issues in developing Countries

- More than 2 million people are estimated to die each year due to indoor and outdoor air pollution (UNEP, 2007)
  - Indoor air pollution (burning of biomass, kerosene or coal for cooking), particularly affects women and children
  - Each year as many as 1.6 million deaths are attributed due indoor pollution, nearly all of them are in developing countries (UNEP, 2007)
  - WHO estimates that almost 800,000 people die each year from outdoor urban air pollution and most of these deaths occur in developing countries (UNEP, 2007;WHO 2002)
- Vehicle emission is one of contributing factors to outdoor urban poor air quality

Impact of indoor air pollution on women and children

Urban air quality issues cont'd

- Estimates of motor vehicles' contribution to urban air pollution worldwide is between 25 – 75% (UNEP and PCFV, 2007)

- In developing countries,
  - vehicle numbers are increasing exponentially (Figure 1)
  - high-sulfur fuels (Figure 4) continue to be the norm
  - inhibit the introduction of new vehicle technologies.
- Given the present poor quality of fuels and vehicles often found in these countries, Urban air pollution problems needs urgent solution

Urban air quality issues cont'd

- Key pollutants of vehicle emissions are (Figure 3):
  - Carbon monoxide (CO)
  - Hydrocarbons (HC)
  - ozone (O_3)
  - Nitrogen oxides (NO_x)
  - Particulate matter (PM)
  - Sulfur oxides (SO_x)

- However, the amount of these pollutants in the atmosphere depend on;
  - the quality of fuels used,
  - age of the vehicle and
  - the design of the vehicles

Major impacts of motor vehicle emissions

- From public health perspective, the main concern are the following pollutants;

1. Carbon Monoxide (CO):
   - It is a colourless, odourless gas produced through the incomplete combustion of carbon-based fuels
   - In developed countries transportation is the major source, accounting for up to 95% of emissions (USEPA, 2001)
   - In developing countries, transportation sources are less important but growing rapidly, with emissions of 9% (EDGAR,2001)

Major impacts cont'd

- Its health impacts are:
  - CO enters the blood stream through the lungs and reduces the delivery of oxygen to the body's organs and tissues
    - Impairing the blood's oxygen carrying capacity- it bonds strongly with haemoglobin in red blood cells
  - At higher level, CO exposure can impair;
    - visual perception,
    - work capacity
    - manual dexterity
    - Learning ability and
    - Performance of complex tasks
  - The health impact of CO is more serious for those who suffer from cardiovascular diseases
  - At sufficient concentrations, CO poisoning can cause death

Major impacts cont'd

2. Hydrocarbon (HC)

- It is also known as volatile organic compounds (VOC)

- Vehicle emissions are responsible for approximately 25% of human-caused HC emissions globally (EDGAR 2001; EPA 2001)

- Vehicle emissions are the major sources due to incomplete combustion process

- hydrocarbons are problematic both because;
  - They are essential precursor for ground level ozone and
  - Many HC species are themselves toxic or carcinogenic

- According to USEPA (2000), vehicle emissions are responsible for 50 – 75% of the HC species. which are known carcinogens:
  - Benzene
  - Acetaldehyde
  - 1,3 Butadiene and
  - Formaldehyde

Major impacts cont'd

- Generally, the impact of elevated exposure of HC emissions can be summarized as:
  - Neurological,
  - Reproductive effects,
  - Respiratory impacts,
  - Cancer and
  - Other serious impacts on pregnancy and infant health

Major impacts cont'd

3. Nitrogen Oxides (NO_x):

- Vehicle emission is the dominant source of NO_x,
  - accounting 50% of emissions (USEPA 2001; gugele and Ritter 2002; EDGAR 2001)
- Nitrogen dioxide is a primary irritant and chronic exposure to elevated levels can lead to increased incidence of acute respiratory diseases in children and lower resistance adults
- NO_x absorbs light, resulting a visible impairment in polluted air
- It is also the principal contributor to eutrophication; the excessive fertilization of lakes, estuarine and bays
  - Eutrophication results in excessive algae growth, which damage other aquatic plants and fish
- Because it is highly water soluble, the primary loss mechanism for NO_x is oxidation to nitric acid (HNO_3),

Major pollutants cont'd

- HNO_3 is one of the two critical acid species in rain, contributing to widespread ecosystem damage of:
  - Lakes
  - Rivers
  - Forests
  - Agricultural crops
  - Soil

- Nitrate can also react in the atmosphere to form nitrate aerosol particles, these also causes;
  - human cancers and
  - Impairing visibility

Major impacts cont'd

4. Particulate matter (PM)

- It is the general term for solid particles or liquid droplets suspended in the air
- Transportation is the major source of PM, which can account 51 – 90 % of the emission (Kathrine *et al*., 2006)
- Particle composition can be an important factor in the health impacts of PM,
  - with soluble organic fraction imparting increased toxicity and mutagenicity
- The smallest particles are very respirable and can lodge deeply in the lunges;
  - resulting in greater health impacts than larger particles

Major impacts cont'd

- Generally, ambient PM have the following impacts;
  - Chronic bronchitis
  - Aggravation of respiratory and cardiovascular diseases
    - ↑ hospital admission and emergency room visits
    - ↑ premature deaths
    - ↑ school absence
    - ↑ Work loss days
    - ↑ Restricted activity days
  - Aggravated asthma
  - Diesel PM is of special concern, because it has associated with an increased risk of lung cancer (USEPA, 2004)
  - Impact visibility
  - Fine particles, especially sulfate and nitrate aerosols also cause material damage and acid deposition

Major impacts cont'd

5. Ozone (O_3)

- Ground-level ozone (bad ozone) has no direct emission sources; it is entirely a secondary pollutant (Table 1)
  - It is formed when nitrogen oxides and HC react in the presence of heat and sunlight (photochemical reactions in the atmosphere)
  - These two pollutants are often referred to as ozone precursors
- It is the major component of urban smog; the pollution that blankets many areas during the summer.
- Its impact includes:
  - Irritation of the respiratory system, which can cause chest pain, coughing, nausea and lung inflammation
  - Reduce lung functions and make it more difficult to breath deeply

Major impacts cont'd

- Inflame and damage the lining of the lungs, which may lead to permanent changes in lung tissue

- Chronic exposure can cause Permanente damage to lungs

- Ambient ozone also affects crop yield, forest growth, and the durability of materials.
  - Because ground-level ozone interferes with the ability of a plant to produce and store food,
    - plants become more susceptible to disease, insect attack, harsh weather and other environmental stresses.

  - Ozone chemically attacks natural rubber and certain synthetic polymers, textile fibbers and dyes, and, to a lesser extent, paints.
    - This makes, natural rubber and polymers become brittle and crack, and dyes fade after exposure to ozone.

Health and environmental impacts of high sulfur fuels

- Sulfur is a naturally occurring component of crude oil and is found in both gasoline and diesel

- Close to 100% of the sulfur in the fuel will be emitted as SO_2 (Kathren et al., 2006)

- SO_2 causes a wide variety of health and environmental impacts

- Particularly sensitive groups includes:
  - People with asthma
  - Children
  - The elderly
  - People with heart or lung diseases

1. Reparatory effects
   - Peak level of SO_2 in the air (Table 3) can cause temporarily breathing difficulty for people with asthma
   - High level of SO_2 gas and particulates cause respiratory illness and aggravate existing heart diseases

Health and environmental impacts cont'd

2. Respiratory effects from sulfate particles
   - SO_2 reacts with other chemicals in the air to form tiny sulfate particles
   - When these are breathed in, they gather in lungs and are associated with increased respiratory diseases;
     - Difficulty in breathing
     - Premature death
   - sulfate particles provide a relatively large surface area onto which HC species condense, resulting in particle growth and increasing particle toxicity (Shi and Harrison 1999).
   - high sulfur levels in diesel fuel increases both PM emissions and the carcinogenic and toxic effects of the particulate matter formed (Bünger et al. 2000).

Health and environmental impacts cont'd

3. Visibility impairment
   - Sulfate particles are the major cause of reduced visibility

4. Acid Rain
   - SO_2 and nitrogen oxides react with other substances in the air to form acids, which fall to earth as rain, fog, snow or dry particles

   - Some may be carried by the wind over a long distance and deposited far from the point of origin

Health and environmental impacts cont'd

Environmental Impacts

Forest and Crop Damages:

- This may be due acid rain or gaseous uptake, the damage can be;
  - Necrosis – killing of tissue or destruction of leaf tissue
  - Chlorosis – loss or reduction of chlorophyll
  - Epinasty - is the downward curvature of leaf due to high rate of growth on the upper surface
  - Leaf abscission – dropping of leaves
- The gaseous uptake of SO_2 by vegetations results;
  - Internal cellular damage or
  - Changes to biochemical /physiological processes

Health and environmental impacts cont'd

SO_2 and NO_x can contribute to acidification of soils;

- Which may be accompanied by a depletion of base cation, affecting the local vegetation over relatively long time scales

Acid rain make lakes and streams acidic and unsuitable for fish

Continued exposed over a long time changes the natural variety of plants and animals in an ecosystem

Effects of sulfur on materials (properties)

- sulfur accelerates the decay of building materials and paints (Table 2)

Why sulfur emission is the major concern?

- Fuel quality intimately affects vehicle emissions,
- because the vehicle and its fuel (and oil) form an integrated system, this system determines the quality and amount of emissions

- Understanding this 'system approach' is key to understand how fuel sulfur affects emission

- Reducing sulfur levels in fuels is important in reducing vehicle emissions in two ways:

- First, reducing sulfur in fuels reduces the direct emissions of:
  - Sulfur dioxide
  - Sulfate particulate matter
  - Other secondary pollutants such as sulferic acid

Why sulfur cont'd

- Second, the availability of high sulfur in fuels reduces the effectiveness of vehicle emission control technologies such as;
  - Catalytic Converters,
  - Diesel Particle Traps,
  - Exhaust Gas Recirculation and
  - Others

- This results in increased vehicle emissions of:
  - Carbon monoxide (CO)
  - Hydrocarbon (HC)
  - Nitrogen oxide (NOx)
  - Particulate matter (PM)

- This is mainly because higher sulfur in fuels:
  - ↑ Fuel injector corrosion
  - ↑ Piston ring corrosion
  - ↑ Oil acidification
  - ↓ Overall engine wear quality

Why sulfur cont'd

- Because of these, vehicle emission control technologies and their associated fuel sulfur limits have evolved dramatically over the past 15 years (UNEP and PCFV,2007)

- To see some example:

- Exhaust Gas Recirculation (EGR)- is a modified engine design where exhaust gas is recycled back to the engine inlet system which reduces combustion temperature and hence NO_x formation
  - The EGR control valve can become corroded with high sulfur level; hence sulfur levels should be restricted to maximum 500 ppm

- Diesel Oxidation Catalyst (DOC)- it is a common emission control device that helps to reduce;
  - Carbon monoxide (CO)
  - Hydrocarbons (HC)
  - Particulate matter (PM)

Why sulfur cont'd

- But higher sulfur levels can poison DOCs and cause them to become ineffective.
  - Then when vehicles are fitted with DOC's diesel fuel sulfur level should be limited to less than 500ppm

- Additional advantages of low sulfur Fuel;
  - Reduce corrosion and acidification of engine oil
  - Leads longer maintenance intervals,
    - thus reduce maintenance costs
  - The presence of sulfur in fuels significantly reduces the life of engines,

Why sulfur cont'd

- Because of these,
  - it is impossible to clean the air or reduce air pollution from the transportation sector, without getting sulfur out of fuels.

  - While transportation is less significant as a direct source of SO_2 (Figure 2)
    - removal of sulfur from gasoline and diesel fuels is critical for the control of other vehicle emissions

Conclusion and recommendation

Conclusion

- public health recognizes air pollution as an important determinant of health, especially in developing countries
- For the last 30 years, air pollution control programs in developed countries have shown that cleaner fuels and vehicles are an effective pathway to cleaner air.
- The benefits of removal of sulfur from transportation fuels are clear. While any level of reduction of fuel sulfur reduces emissions of SO_2 and sulfate PM, further emission benefits obtained with larger step-down reductions
- Imported used vehicles or engines remain a serious problem in in many developing countries and these old vehicles or vehicles with little or no functional pollution controls are a major source of emission in many countries

Conclusion and recommendation cont’d

Recommendations

- **Reducing emissions from motor vehicles** is an important component of an overall strategy for reducing air pollution, especially in developing country cities.

- Options to reduce fuel sulfur
  - **Countries without refineries**
    - can lower their sulfur levels by purchasing it on world markets.
  - **Countries With Refineries**
    - **Switch to lower sulfur crude oil**
    - **Desulfurisation of blending components**

Conclusion and recommendation cont'd

- Importation of lower-sulfur fuels has also been a step taken by countries with refineries, but whose refineries are still in the process of being upgraded.
  - For example, India and the Philippines

- The following approaches have been demonstrated to stop or drastically reduce the problem of importing used vehicles;
  - Ban import of certain types of used vehicles or engines,
  - Place a high tax on imported used vehicles or engines,
  - Require imports to pass a stringent emission requirements as a condition of registration
  - Creating favourable conditions that encourage the importation and purchase of new vehicles or engines, relatively low pollution vehicles

THANK YOU

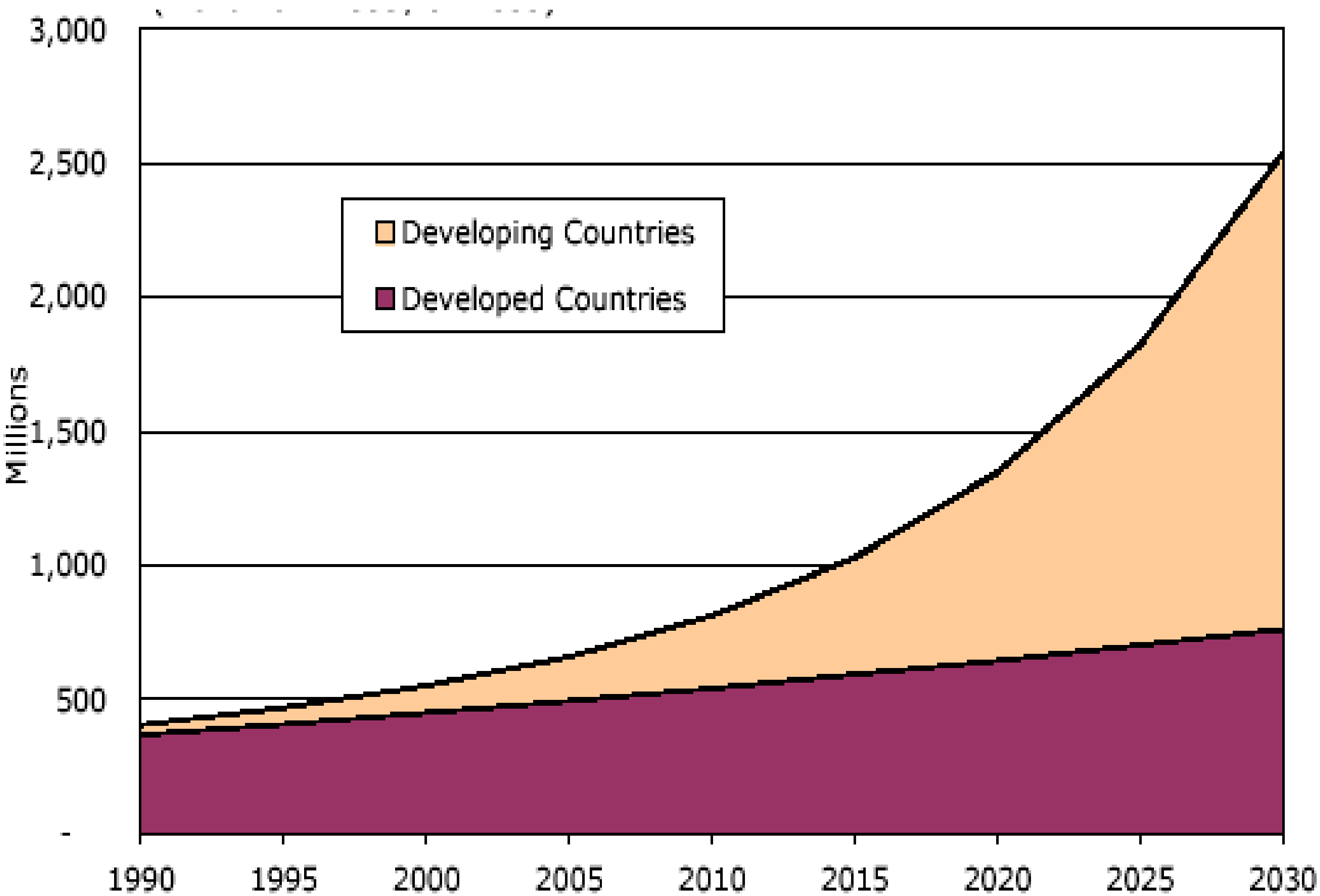

Figure 1 Projected Number of cars in developing and developed countries (World Bank, 1999

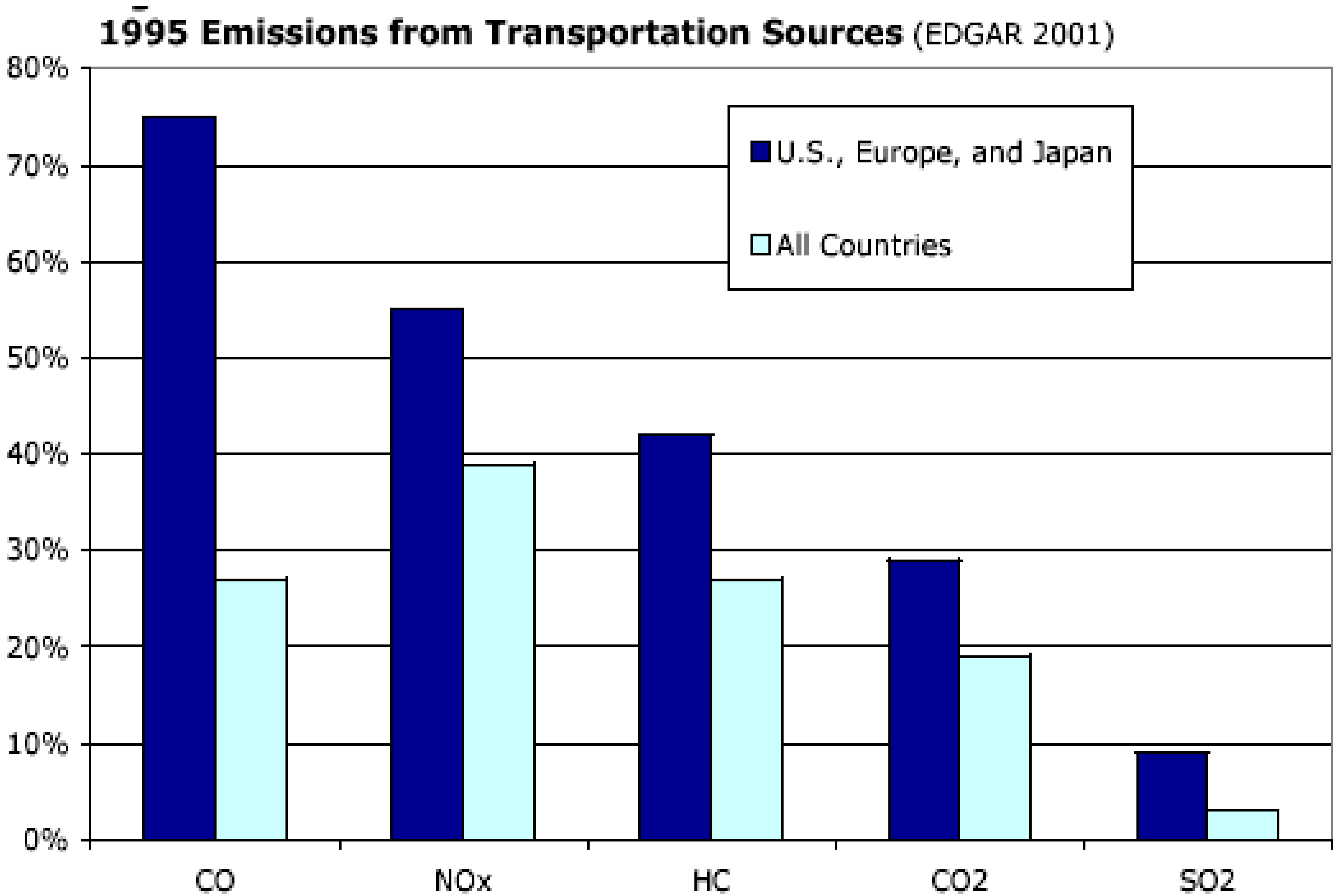

Figure 1995 Emissions from Transport sources

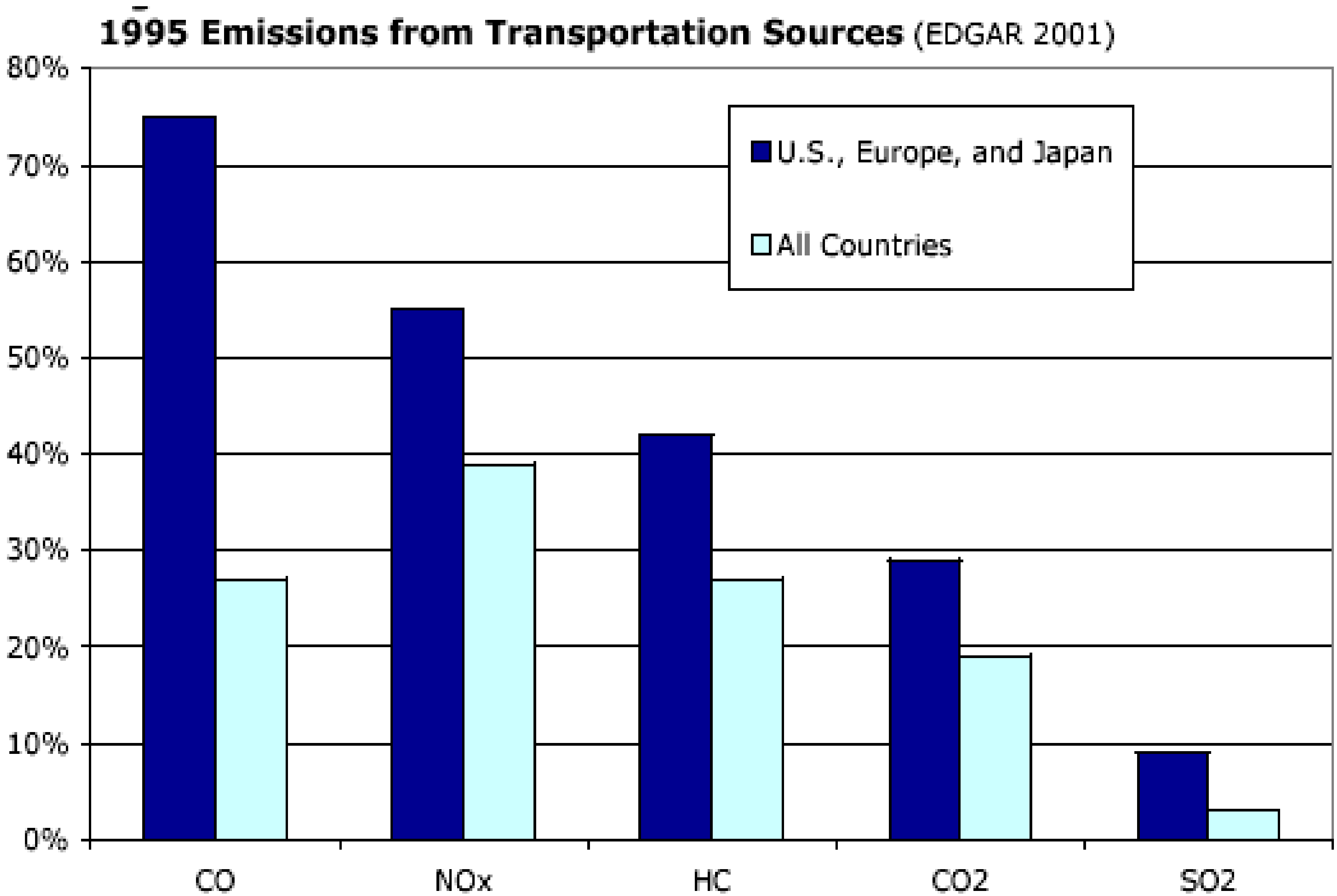

Figure 1995 Emissions from Transport sources

What is the current sulfur content of fuels?

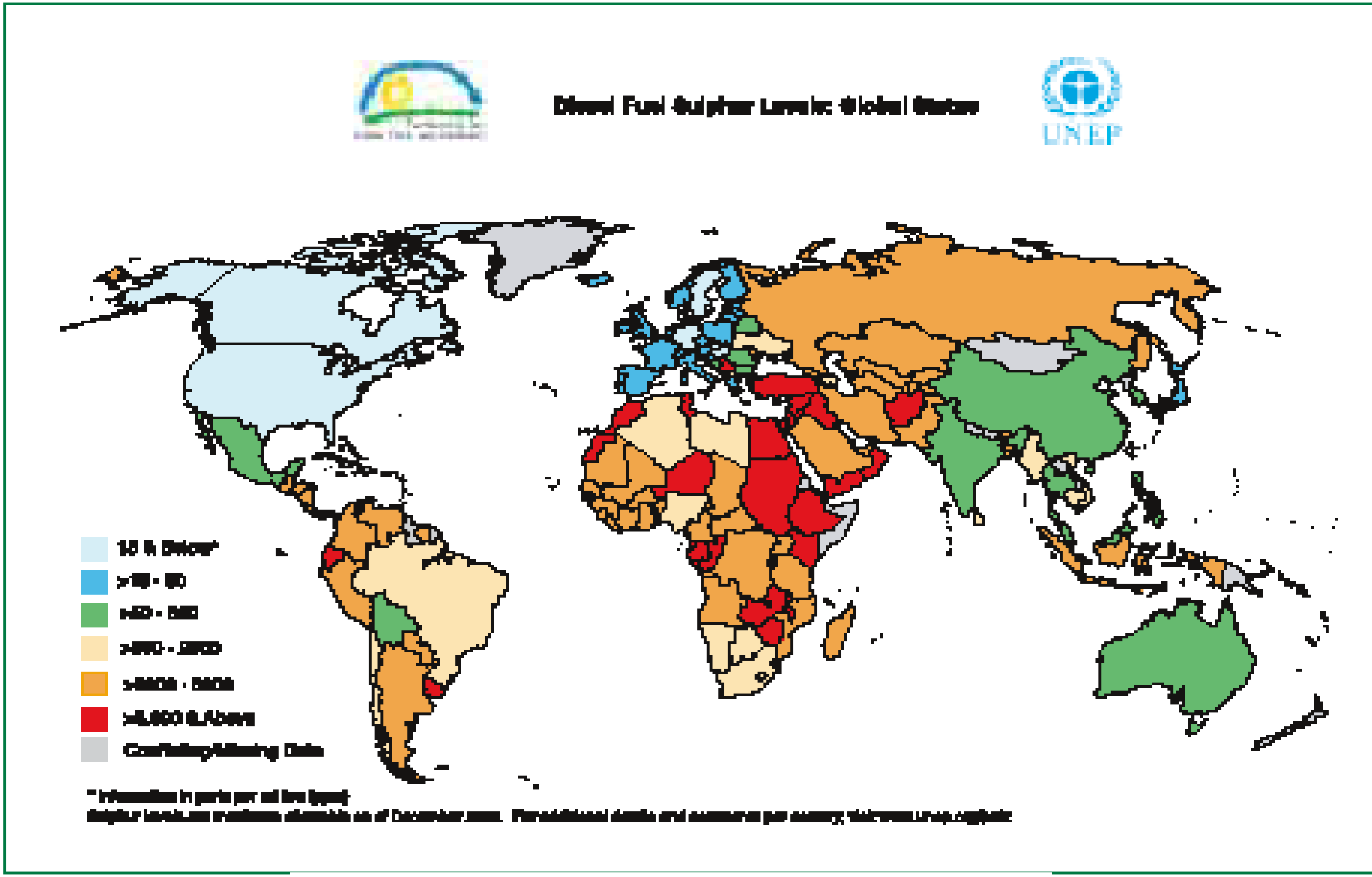

Figure Sulphur levels in diesel fuels in parts per million as of December 2006

Source: UNEP and PCFV, ---

Table 1: types of primary and secondary pollutants

No	type	Primary pollutant	Secondary pollutant
1	Sulfur compounds	SO_2, H_2S	SO_3, H_2SO_4
2	Nitrogen compounds	NO, NH_3	NO_2, HNO_3
3	Carbon oxides	CO, CO2,	none
4	Oxidants	None	O_3

Table 2: Harmful effects of sulfur on materials

No	Material	Effect	Of Type Pollutants
1	Metal	Corrosion, discoloration, soiling	SO_2, H_2SO_4, PM, H_2S
2	Stone and concrete	Surface corrosion, discoloration, soiling	SO_2, H_2SO_4, PM, H_2S
3	Ceramics and glass	Surface corrosion	H_2S, PM
4	Paints	Discoloration, soiling	SO_2, H_2S, PM
5	Paper	Embrittlement, discoloration	SO_2
6	Leather	Surface deterioration	SO_2
7	Textiles	Deterioration, fading, soiling	SO_2, PM

Table 3: Updated WHO Air quality guideline values (WHO, 2005)

Pollutant	Averaging time	AQG value
Particulate matter		
$PM_{2.5}$	1 year 24 hour (99th percentile)	10 µg/m³ 25 µg/m³
PM_{10}	1 year 24 hour (99th percentile)	20 µg/m³ 50 µg/m³
Ozone, O_3	8 hour, daily maximum	100 µg/m³
Nitrogen dioxide, NO_2	1 year 1 hour	40 µg/m³ 200 µg/m³
Sulfur dioxide, SO_2	24 hour 10 minute	20 µg/m³ 500 µg/m³