The health impacts of particulate matter in diesel exhaust emissions
(with a focus on cancer)

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Neil Hime
Diesel exhaust

• **Particulate matter (PM)**

• Gases – carbon dioxide, carbon monoxide, oxygen, nitrogen, nitrous oxides, sulphur dioxide, volatile organics, polycyclic aromatic hydrocarbons (PAH)

• Diesel exhaust includes >40 substances that are listed by the US EPA as hazardous air pollutants (15 of these are listed by the IARC as carcinogenic to humans, or as a probable or possible human carcinogen)

  Chemical reactions in the atmosphere result in (secondary) PM (including particulates with carcinogenic properties) being formed from the emitted gases in diesel exhaust
The health impacts of PM exposure

• ↑ mortality (↓ life expectancy)
• Respiratory health effects (generally impacting already existing disease)
• Cardiovascular health effects (generally impacting already existing disease)
• **Cancer**
• Central nervous system effects
• Developmental effects

WHO (2013) Review of Evidence on Health Aspects of Air Pollution (REVIHAAP Project)
Global Burden of Disease Study 2010
A comparative risk assessment of 67 health risk factors

- Based on disability-adjusted life years (DALYs)
- One DALY can be thought of as one lost year of “healthy” life
- DALYs combine measures of years of life lost and years living with a disability

Outdoor PM air pollution
- 9th ranked risk (world)
- 4th ranked risk (East Asia)
- 26th ranked risk (Australasia)

380:224-2260
PM exposure and cancer
- Evidence of an association

- American Cancer Society
- Harvard Six Cities
- Nurses’ Health

All very large cohort studies in the US, found significant associations between outdoor PM$_{2.5}$ levels and lung cancer incidence and mortality (all adjusted for smoking)


Across 17 cohorts in 9 European countries:
a 10 µg/m$^3$ increase in personal exposure to outdoor air PM$_{2.5}$ and PM$_{10}$ was significantly associated with increases of 40% and 22% in lung cancer incidence, respectively

Sufficient evidence to conclude that “exposure to outdoor air pollution causes lung cancer”

“exposure to outdoor air pollution was positively associated with an increased risk of bladder cancer”

“the findings regarding carcinogenicity of outdoor air pollution as a mixture, and of PM specifically, are remarkably consistent”
Diesel exhaust PM

- Diesel exhaust particles have a core of elemental carbon surrounded by organic compounds, sulphate, nitrate, metals and other trace elements including toxics – PAHs and their derivatives and, some metals (chromium, nickel) are known to have mutagenic and carcinogenic properties.

- Diesel exhaust particles from modern engines are primarily fine particles (PM$_{2.5}$); including a considerable component of ultrafine particles (PM$_{0.1}$). PM$_{2.5}$ penetrate deep into the lung and PM$_{0.1}$ have been shown to cross from the airways into the blood.
• Strong evidence that exposure to outdoor air (ambient) PM is associated (and likely causal) for health effects (including cancer (lung))

• The chemical composition and size of diesel exhaust particles suggest that these particles have the potential to cause health effects (including cancer)
Diesel exhaust exposure and cancer - evidence of effect

- Overwhelming evidence from animal and cell culture studies that diesel exhaust PM causes DNA damage and lung tumours in a dose-response manner


Meta-analysis of studies that provided estimates of the relative risk of developing lung cancer in occupations with substantial exposure to diesel exhaust (compared to the absence of such exposure)

• Studies allowed for adequate latency period (≥10 years) after exposure

• Mining occupations excluded because of potential confounding by other exposures (e.g. silica, arsenic)

• Occupations included: truck drivers, railway workers, mechanics, professional drivers

• Excluding studies where exposure to diesel exhaust could not easily be distinguished from other engine exhaust exposures, occupations with substantial exposure to diesel exhaust were associated with a 47% increase in relative (not absolute) smoking-adjusted risk of lung cancer

• Suggestive evidence of exposure-response relationship supports occupational diesel exhaust exposure being causative for lung cancer
Over 12,000 mine workers from 8 US, non-metal mines
Diesel exhaust exposure (quantified from work histories and air measurements at mine sites) was positively associated with lung cancer mortality

Exposure-response relationship for lung cancer mortality has been demonstrated in US railway workers. The relationship was only evident in workers hired after 1954, the year that diesel locomotives were introduced.

- US EPA’s first comprehensive review of the potential health effects from ambient (non-occupational) exposure to exhaust from diesel engines

“Long-term inhalation exposure is likely to pose a lung cancer hazard to humans”
In 2012, the IARC classified diesel engine exhaust as “carcinogenic to humans”
The IARC stated:

“Diesel engine exhaust causes cancer of the lung”

“A positive association has been observed between exposure to diesel engine exhaust and cancer of the urinary bladder”

• Dose-response relationships cited by the IARC support exposure to diesel exhaust being causative for lung cancer

• Positive exposure-lung cancer risk associations remained after results were adjusted for smoking
The conclusion of the IARC was based on evidence from:

- studies of cohorts of workers exposed in their occupations (railway workers, bus garage workers, bus drivers, truck and other professional drivers, miners, other professions exposed to diesel exhaust)

- case-control studies in occupationally exposed populations

- case-control studies in the general population, where exposure to diesel exhaust was estimated from occupational exposure

- animal studies
• The IARC report did not include evidence from studies of environmental (non-occupational) exposures

• Their reasoning was that ambient pollution comprises emissions from many sources

“At present, it is very difficult to assess the specific contributions of these sources to the observed cancer risk. These environmental studies...would contribute little information in addition to the studies reviewed” (IARC 2012)
Notwithstanding that risks identified in heavily exposed occupational groups could precede positive findings in the general population, currently the health risks of environmental (non-occupational) exposures to diesel exhaust are largely unknown.

The evidence from occupational exposures used by the IARC relates to the whole diesel exhaust mix of gases and particles. Generally the only evidence specific to diesel exhaust PM comes from animal and cell culture studies (and a few controlled exposure studies in humans)
Not all investigations support diesel exhaust exposure causing cancer

- Systematic literature review conducted since publication of the IARC report concluded that neither 42 cohort studies nor 32 case-control studies indicated a clear exposure-response relationship. The lack of objective measures of exposure cited as the main problem with the evidence (with exposure assessment usually based on work histories and not direct measures of exposure).


- It has been suggested that occupational epidemiological evidence based on weak exposure-response associations could be explained by bias, confounding, chance or exposure misclassification.

However,

The majority of epidemiological evidence suggests a causal relationship exists between occupational diesel exhaust exposure and the incidence of lung cancer.
Other health effects associated with diesel exhaust exposure

• Occupational exposures have been associated with cough, chest tightness, wheezing, chronic bronchitis and decreased lung function

• Controlled exposures in human volunteers has adverse cardiovascular effects (heart rate, blood pressure, clotting), respiratory effects (inflammation, airway resistance), enhanced immune responses, eye and nasal irritation

• Exposure of animals to diesel exhaust PM has been shown to progress influenza and other viral infections, enhance the allergic response to pollen and dust mites, increase atherosclerosis in an animal model of cardiovascular disease and, result in adverse birth outcomes when pregnant animals were exposed
Review of evidence of the health impacts of source-specific PM

Written by The Woolcock Institute of Medical Research for the NSW EPA and NSW Health

Includes chapters on the health effects of on-road and non-road diesel exhaust

Will be available in the coming month on the websites of The Woolcock Institute of Medical Research and NSW EPA

http://woolcock.org.au/