Biodiesel Breathes Better

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It is long-established that car exhaust fumes cause respiratory disease, and more recently the particulate matter in diesel exhaust has been implicated in the death of human airway cells. However, new research reveals that biodiesel is a safer alternative.

Driving a vehicle is one of the most polluting activities that the average person carries out. More people are driving cars, with rapidly developing countries like China putting 1000 new cars on the street every day. Furthermore, people in affluent countries are driving bigger cars today than they were a decade ago. Four wheel drive vehicles are a common sight in the inner suburbs of Australia’s cities, and these generally produce more greenhouse gases and other exhaust emissions compared with passenger cars.

The combustion of fossil fuels by vehicles generates a plethora of chemical compounds that are released into the atmosphere. Although many of these, such as nitrogen and water, are relatively harmless, noxious substances such as carbon monoxide, nitrogen oxides and hydrocarbons are also produced.

Another important class of by-product found in vehicle exhaust is the particulate matter derived from burnt fuel. Such particles comprise a carbon core that binds heavy metals and organic compounds.

Particles that are larger than 10 μm in diameter can cause irritation to the eyes, nose and throat, but are not considered a serious problem as they do not reach the lungs. In contrast to this, smaller particles that are 0.1–10 μm in size are detrimental to human health. Due to their small size, these particles can lodge in the airways and lungs where they can interfere with the functions of cells and thus cause disease. The particles from diesel exhaust fit into this category as they are typically 0.1 μm in size.

Epidemiological studies have linked particulate matter pollution to increased risk of hospitalisations for respiratory diseases including asthma, emphysema and chronic bronchitis. This has a significant impact on human health as respiratory diseases are a major cause of illness in Western countries. The marked increase in the prevalence of asthma in the past 30 years has been attributed to exposure to particulate matter.

Particulate matter stimulates inflammatory responses in the body and is associated with death in susceptible populations, including the elderly and those with pre-existing respiratory or cardiopulmonary disease. It has been estimated that particulate matter is directly responsible for up to 50,000 deaths per year in the USA and 200,000 deaths per year in Europe.
The seed from *Jatropha* is used as a source of oil for the production of biodiesel. Other plants used as a source of biodiesel include rapeseed, sunflower and soybean.

**BIOFUELS FROM PLANTS**

Many solutions to reducing vehicular emissions have been proposed, the most obvious one being a reduction in the use of vehicles. This, however, is not a readily acceptable proposition for many people who have come to depend on this form of transport.

The replacement of fossil fuels with biofuels that have a more environmentally friendly image is currently receiving much attention. Biodiesel fuel is made from vegetable oil or animal fats, and has properties similar to petroleum-based diesel fuel.

An example of a plant that is used to produce biofuel is *Jatropha*, the seed of which is used as a source of oil. Other plants used as a source of biodiesel include rapeseed, sunflower and soybean.

A major reason for considering biodiesel as an alternative source of fuel is that less greenhouse gases are produced overall compared with the gases produced during the combustion of diesel fuel. While the combustion of biodiesel produces similar levels of carbon dioxide emissions to those from fossil fuels, the plants from which the biodiesel is derived absorb carbon dioxide during their life. This compensates for the carbon dioxide produced during combustion so that, overall, combustion of biodiesel may produce just over half the greenhouse gas emissions of fossil fuels.

However, this estimation does not take into account the increased land use that is required to support the growth of crops to produce biofuels. There is evidence that deforestation, one of the most environmentally devastating activities, may be used to generate more land for such crops.

Furthermore, the rush to turn food crops such as maize, wheat, sugar and palm oil into fuel for cars, without first examining the impact on global hunger, may have disastrous consequences on a global scale. Biofuel crops could compete for arable land that is required to sustain food production in some countries, generating a “food versus fuel” conundrum.

In terms of the direct effects of exhaust emissions on human health, comparisons of the products of combustion, unburned components and particulate matter have been made between petroleum-based diesel and biofuels. Overall, biodiesel emissions are lower than diesel emissions.

Furthermore, emissions from the combustion of biodiesel made from plants such as *Jatropha* contain reduced levels of many pollutants. These include fewer hydrocarbons, nitrogen oxides and particulate matter.

However, most of the tests performed on emissions from diesel and biodiesel have been limited to analyses of gaseous pollutants. Less is known about the particulate emissions from biodiesel.

As particulate matter has significant adverse effects on the human airways, our current research has sought to compare the relative effects of particulate matter from biodiesel and diesel.

**BIO DIESEL VS DIESEL TOXICITY**

To test whether the particulate matter from biodiesel was less toxic to human airways than diesel exhaust, we first developed a method to extract the particulate matter from exhaust fumes. This involved collecting smoke-laden exhaust from a 1979 Volkswagen Golf with a 1.6 litre engine onto filter papers. The particulate matter from the filters was removed using an organic solvent, evaporated and...
dissolved in ethanol.

To model the human airway passages in sufficient detail we grew human airway cells in culture. Cultured human airway cells have a paved brick appearance that is similar to how they look in the body, where they line the airways. These airway cells are the ones that are directly exposed to the pollutants that we inhale.

The airway cells grown in culture were exposed to concentrations of particulate matter from diesel exhaust and from biodiesel exhaust for a period of 5 days. At the end of this time the cells were harvested and analysed for toxic effects.

**The Result**

A key finding of our study was that diesel exhaust particulate matter caused cultured airway cells to fuse together to form multinucleated cells. Each multinucleate cell contained up to eight nuclei per cell.

Interestingly, this result is consistent with observations reported in the literature showing that multinucleated cells may be formed as a consequence of different types of damage. Such past studies have reported the presence of multinucleated cells as a common feature of different types of airway pathology. Multinucleated cells have been found in many cases of occupational exposure to airborne substances including silicon, coal dust and metals, in particular cobalt and nickel.

A novel finding of our study was that diesel exhaust particles induced the death of the airway cells through a process called apoptosis or programmed cell death. Apoptosis is a normal cellular process that is used to eliminate damaged cells, but it can also be triggered by toxic substances.

Apoptosis can be detected by the presence of specific cellular changes. This can be seen in the photograph below, where the cells on the left side were treated with diesel, causing their internal skeleton (seen in pale green) to disintegrate or clump together. On the right hand side, cells treated with biodiesel have an intact internal skeleton and show no adverse effects.

**Conclusion**

The overall conclusion of our work was that although both biodiesel and diesel exhaust fumes produce particulate matter, the particles produced from the burning of biodiesel are much less damaging to the cells than the particles produced by burning diesel. This was revealed through changes that were seen in human airway cells grown in cell culture, where the particulate matter from diesel exhaust induced cell death, accompanied by disintegration of their internal structures.

From our study we would predict that inhaling diesel fumes has a more detrimental effect on our health than breathing in biodiesel fumes due to the damaging effect of diesel particulate matter on airway cells. Given the level of cell death we found in this study, diesel exhaust is likely to be a significant contributing factor to respiratory disorders such as asthma. In contrast, the particulate matter from biodiesel is less toxic.

While the results of our work may support a case for the use of biodiesel as a fuel based on its reduced impact on human airway cells, there are many other issues that must be taken into account in assessing the relative impacts of utilising biodiesel rather than diesel fuel. These include environmental concerns that would arise from increased cultivation of crops for biodiesel production.

Such concerns must be taken into account to obtain a balanced perspective of the relative merits of the relative use of fossil fuels versus biofuels.

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