Spectrum

A closer look at diesel exhaust

If you've been stuck in heavy traffic behind an old bus belching diesel fumes you may well have wondered firstly whether anybody knows what's in the emissions and secondly whether they may be bad for your health. The answer to both questions is yes.

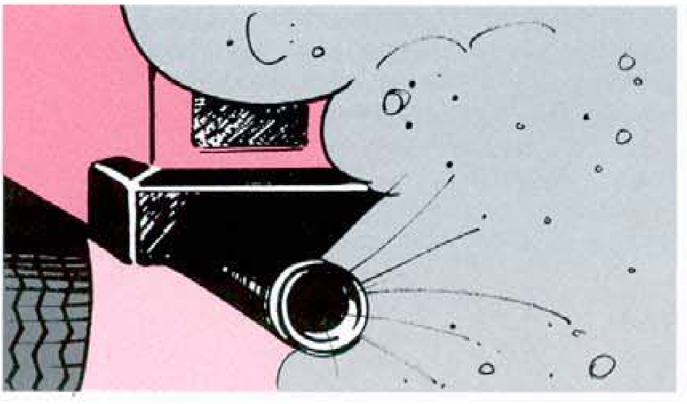
But whether the potentially harmful substances in the exhaust originate from unburnt or combusted diesel fuel — or a combination of both — has only recently been investigated. Dr Peter Nelson of CSIRO's Division of Coal Technology has found that, contrary to the conclusions of other scientists, the organic components of diesel exhaust come from both sources. This is an important finding for engineers designing appropriate emission-control strategies.

Most of the particles that come out of a diesel exhaust pipe are combustion-generated soot; this gives diesel exhaust emissions their characteristic appearance. Unfortunately, combined with the soot is a complex mixture of hydrocarbons — polycyclic aromatic hydrocarbons (PAH) to be precise — known to produce cancer and to cause genetic mutations in laboratory animals.

Chemists originally named some hydrocarbons 'aromatic' because they had pleasant aromas; the volatile oils of cloves, cinnamon, vanilla, etc. contain examples. Later, the term 'aromatic' lost its non-technical meaning, and chemists broadened the concept to include any compound derived from benzene. 'Polycyclic' refers to the chemical structure — two or more benzene rings joined together.

Because of the large number of PAH compounds that exist and the toxicity of many, up until the early 1980s research into vehicle emissions concentrated on accurately identifying and describing the chemical structures of those present. This work did not differentiate between PAH compounds originating from unburnt fuel and those formed during combustion.

When scientists did begin to carry out studies of that sort, they found many of the compounds to be the same as those present in unburnt fuel, and assumed they had originated there. However, in a recent analysis of the diesel emissions from a small diesel truck running on a chassis dynamometer at the New South Wales State Pollution Control Commission's motor-vehicle testing laboratory, Dr Nelson found that the major aromatic components were actually generated by the combustion process.



He thinks that the equipment used in earlier experiments was probably not efficient enough to trap the more volatile compounds. Nevertheless, he believes the unburnt fuel is the most likely source for the PAH compounds known to be most toxic.

So far, control technologies for the reduction of diesel exhaust emissions have concentrated on engine modifications to optimise efficiencies. Recently, however, some vehicle manufacturers have introduced exhaust filters that decrease emissions of soot and PAH. In the future these will become more common.

Clearly, technologies to eliminate the harmful components of diesel exhaust will need to recognise the relative importance of burnt and unburnt fuel.

David Brett

Combustion-generated polycyclic aromatic hydrocarbons in diesel exhaust emissions. P.F. Nelson. *Fuel*, 1989, **68**, 283–6.

Turning wood residues to gold

The wood that remains after sawing round trees into square timber has seldom been worth very much. Now, a new CSIRO process can convert this residual wood into a product worth several thousand dollars a tonne — pelletised, activated charcoal.

For many years, the scientist behind the process, Dr Paul Fung of the CSIRO Division of Forestry and Forest Products, has been working on ways of converting wood residues into useful carbon products and energy for heating and/or generating electricity.

Central to Dr Fung's work is fluidised-bed combustion, a method of burning fuel in a suspension of an inert material such as sand, through which air is blown. The sand acts as a heat reservoir and the air, as well as supplying adequate oxygen, keeps the mixture moving — much like a boiling fluid.

It doesn't take long to find examples of 'fuel' that industries combust in this way:

If, as expected, the field trials show that the CSIRO pellets (on left) perform at least as well as the expensive imported coconut-shell carbon, the gold-mining industry could switch to the home-grown product.

coal slurries, abattoir wastes, rice hulls, sewage sludge. Almost anything organic can be incinerated in a fluidised bed (see *Ecos* 26). The Division has a particular interest in utilising the residue from the timber industry — bark, sawdust, slabs, edgings, and dockings.

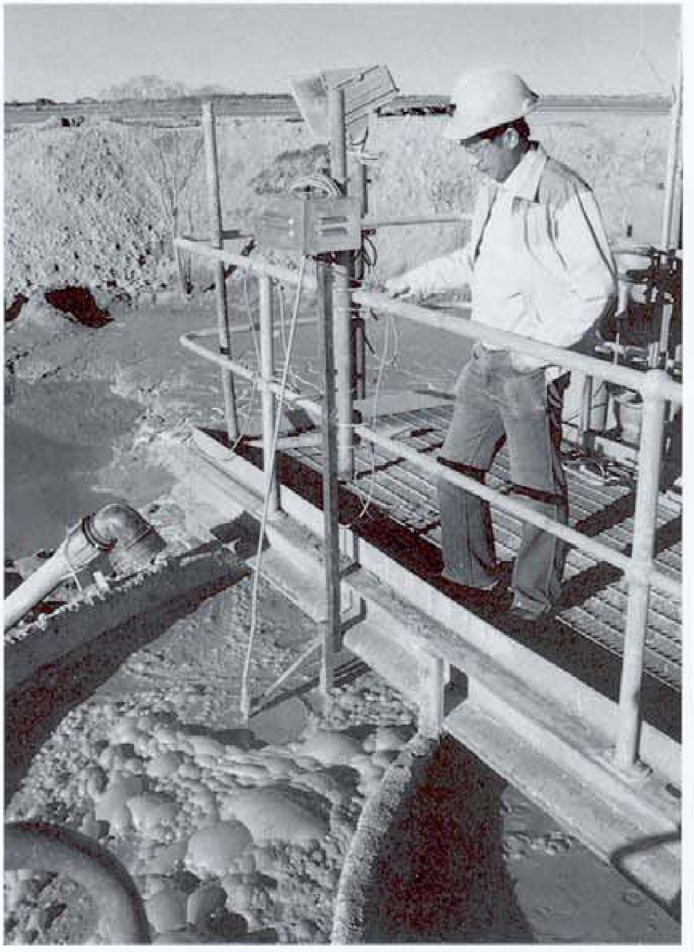
Of a typical log entering a sawmill on its way to becoming seasoned timber, 40–65% ends up as residue. And it's not unusual for a further 25% to become sawdust and shavings as a result of machining and dressing the dried timber. Each year in Australia, this all adds up to about 3 million cubic metres. Although some of the material is used for craft work and in the production of particle board, hardboard, and wood pulp, much of it is unsuitable for such purposes.

Traditional ways of getting rid of organic waste — burning or dumping — are generally expensive and usually polluting. Dr Fung and Mr Ron Liversidge had earlier developed an incinerator that cleanly burnt all the waste produced in a mill. (*Ecos* 4 describes how it works.)

By contrast, combustion in the new CSIRO fluidised-bed process creates not only a valuable charcoal by-product but enough energy to meet a sawmill's needs. In fact, combustion of only 20% of the average hardwood mill's residues would give it all the energy it needs (mainly electricity, and the heat for kiln drying).

Compared with making charcoal in batch kilns, the CSIRO process is non-polluting and much more efficient; smoke and volatile chemicals are burned and converted into more energy. The feedstock does not have to be dry, but must be coarsely chipped to be handled in the fluidised bed.

Having developed an efficient 'energy plus charcoal' process, Dr Fung turned his attention to the quality of the charcoal produced. Bags of barbecue charcoal in stacks at the local service station remind us of a familiar use for the product, but high-value, or high-volume, uses are also found in the pharmaceutical industry, aluminium and silicon production, and gold extraction.



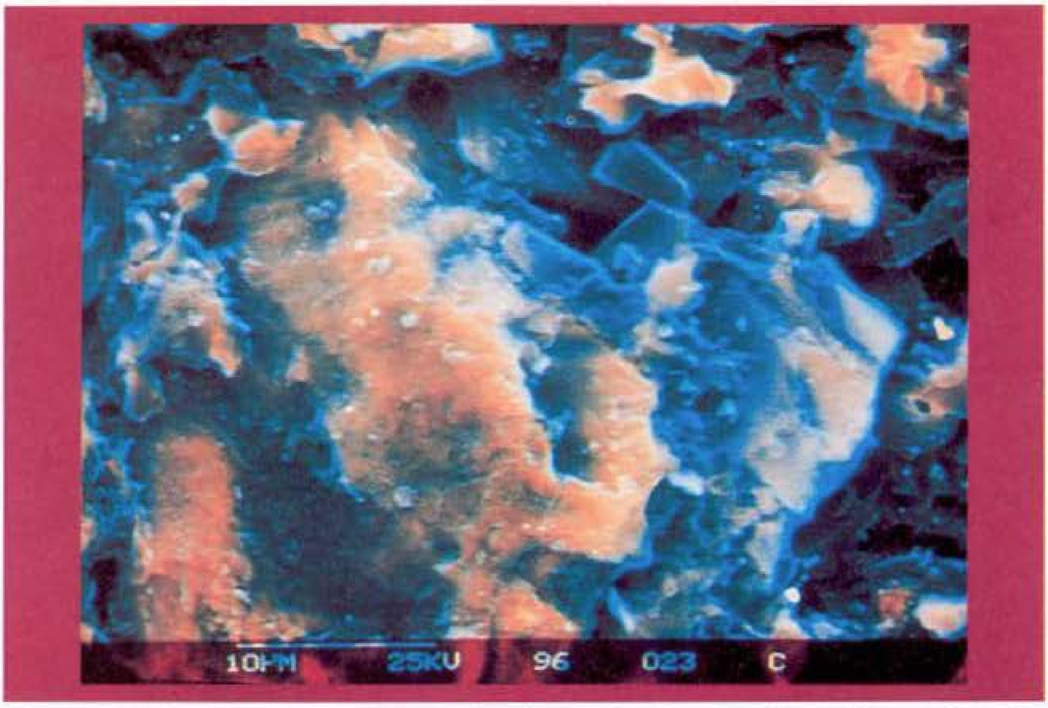
When activated carbon is added to the powdered gold and cyanide solution, it selectively adsorbs the gold. Here, Dr Paul Fung tests a sample of his jarrah carbon pellets.

To identify market opportunities for charcoal sales, the Division worked closely with CSIRO's marketing company, Sirotech. They focused their attention on the gold-mining industry, which requires a very specific quality of charcoal, consumes about 5000 tonnes per year, and imports all of it — at a cost of $4–6500 a tonne. The challenge was to develop a product that would meet the industry's exacting standards at a price that would encourage local manufacture.

Gold-miners use activated carbon — a very clean carbon with a myriad minute pores that are excellent adsorbers; the pores in a few grams have a total surface area greater than the size of a football field. In the gold-refining process, ore is first crushed to a powder, then mixed with a cyanide solution and churned to introduce atmospheric oxygen. The gold dissolves to form a cyanide complex, but, unfortunately, many other metals behave in a similar way.

When activated carbon is added to the solution in what is known as the carbon-in-pulp process, it selectively adsorbs gold, even though the gold concentration is very low. The gold-laden carbon is then 'stripped' with fresh cyanide at a raised temperature and pressure to produce gold. The charcoal is then cleaned (by heating) and recycled.

The major current sources of activated carbon for gold recovery are coconut shell and peat. These carbons have good gold-adsorption properties and tend not to disintegrate into small particles, or 'fines'. This is important because gold attached to the fines is lost in



Above: **Gold adsorbed within the CSIRO carbon. The scanning electron micrograph was enhanced using a 'real-time colour imaging system' developed by the Division of Forestry and Forest Products.**

Below: **Making charcoal in the Division's fluidised-bed combustion plant.**

the filtering process.

In a series of trials, Dr Fung's research team compared activated carbons made from jarrah (*Eucalyptus marginata*) with commercial coconut-shell carbons commonly used by the industry. The scientists tested those properties that the industry considers most important: the rate of gold adsorption, gold-stripping capacity, and hardness.

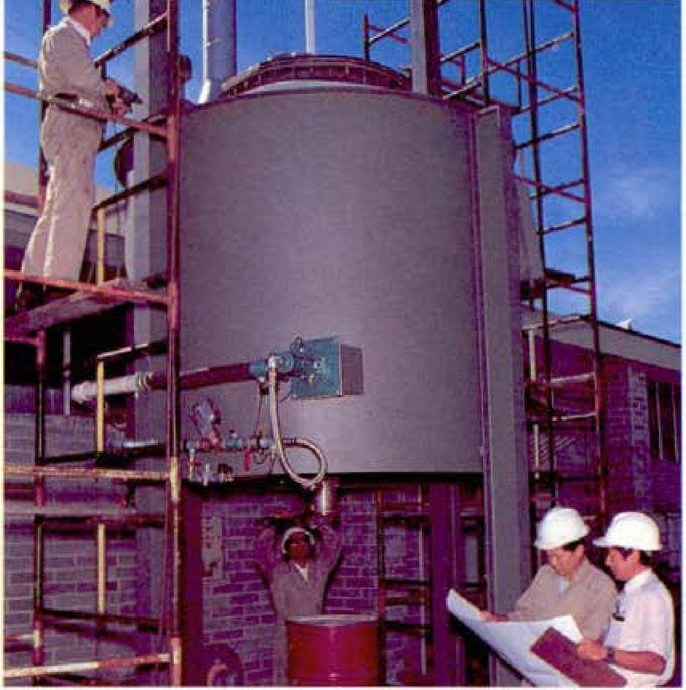
For the first two, the jarrah carbon proved to be significantly better than its competitors. However, for the standard hardness test — the carbon is shaken with steel balls and given a hardness number between 0 and 100 — the jarrah carbon (at 85–90) proved significantly softer than coconut-shell carbons (97–9).

Because the industry felt that the improvement of two properties did not compensate for the greater softness, the research team focused on improving the charcoal's hardness. They sought to produce a composite material that retained its superior gold-adsorption and stripping properties and could withstand high temperatures associated with recycling, but was hard enough to meet industry standards.

The research led to the development of composite charcoal pellets resembling tiny lengths of burnt spaghetti.

After laboriously making several hundred of these small pellets by hand, and testing them in the laboratory, the team produced a re-formed charcoal that retained its good gold-adsorption qualities but rated a hardness of 99·6, exceeding that of any carbon commercially available. A small trial at a gold-mine confirmed the excellent properties of the new product.

As *Ecos* goes to press, work is concentrating on scaling-up pellet production. Members of Dr Fung's team have nearly finished building a small plant



This plant will be able to produce large quantities of pellets.

that can produce the pellets in large quantities — they need at least a tonne for a full-scale operational trial. The Division is also negotiating with an Australian company to produce fluidised-bed charcoal and to manufacture the activated and reinforced product.

A manufacturer should be able to produce the CSIRO pellets at a price competitive with that of high-grade imported charcoal. (Coupled with that, the product's low cost of distribution relative to its high value will make it an attractive export.) And the full-scale trial — if, as expected, it shows that these home-grown pellets are more cost-effective than competitive imports — will give the gold-mining industry a big incentive to switch. If that happens, turning wood into gold will have become more than an alchemist's dream!

David Brett

Properties of carbon from *Eucalyptus marginata* related to its potential applications for activated carbon, electrodes and silicon production. P.Y.H. Fung and T. Brown. *Proceedings of 18th IUFRO World Congress, September 7–21, 1986 Ljubljana, Yugoslavia.*

Study on the production and properties of activated carbon from *Eucalyptus marginata* for gold extraction. P.Y.H. Fung. *Proceedings of 22nd Forest Products Research Conference, 17–20 November, 1986, Melbourne*.

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