Where does bushfire smoke go after it has drifted away from a fire? In *Ecos* 9 we reviewed the work of the Bushfire Section of the former CSIRO Division of Applied Chemistry. This group of scientists had been looking into the chemical composition of the smoke, tracking where it went, and seeing how it behaved.

On the trail of bushfire smoke

After studying many Western Australian prescribed burns, the researchers had concluded — among other things — that the smoke always spread out downwind of the fire in a narrow fan with an angle of 12–13°, regardless of the wind speed.

Such information makes it possible for forestry authorities to plan prescribed burns so that their smoke will stay clear of populated areas. It also allows pilots of light aircraft to be warned where they may expect to encounter smokey skies.

The research did not, however, reveal where the smoke ultimately went, nor did it make it possible to predict how much a plume would reduce the visibility at any given location — information that would be particularly useful for ensuring the safety of low-flying aircraft.

These questions have now been answered as a result of recent studies of smoke plumes from prescribed burns in Western Australia. The observations were made by Mr David Packham and Dr Bob Vines, who are now located in the CSIRO Division of Building Research. (They represent the ghost of the former Bushfire Section, which was disbanded in 1974.)

A smoke column rises from a prescribed burn in the south-western part of Western Australia.

Some smoke lost?

The earlier studies of that Section had indicated that the total mass of particulates in the smoke changed very little during the first 2–3 hours after being formed. Nevertheless, it seemed very possible that with time a proportion of this smoke would be lost by one or all of four ageing mechanisms:

- evaporation of the more volatile components
- oxidation of the carbon-containing constituents
- agglomeration of the particles, which may then settle out
- separation of the smoke from the column by fragmentation at the edges.

Knowing the total mass of the smoke particulates gave no indication of what was happening to the individual particles — were they slowly clumping together, especially in thick smokes of the type often coming from controlled burns?

Researchers in several countries have shown that particles do clump together as they are formed in the flames, but shortly afterwards they become more stable, by which time they have a diameter of about one ten-thousandth of a millimetre. A few larger particles nearly always occur in bushfire smoke as well.

To sort out what was happening, Mr Packham and Dr Vines decided to count particle numbers in bushfire smoke as well as measure its total mass as it moved downwind from a fire. If particle numbers became fewer for a given mass of smoke, then agglomeration was presumably taking place. All measurements were carried out in the smoke plumes emanating from controlled burns in the region of Perth, W.A.

Where does it go?

The scientists' early flights through such plumes indicated that particle numbers weren't varying much as the smoke moved away. They were able to clinch the argument during November 1976, with a large burn ignited from the air at Harvey, rather more than 100 km south of Perth. This fire burnt under almost ideal conditions.

By taking two sets of smoke samples from an aircraft, 1½ hours apart, the scientists were able to sample the same smoke parcel twice as it drifted downwind. Their results showed clearly that little agglomeration of particles had occurred during that time. The mass of the parcel of smoke sampled also had not changed.

Measurements taken 3 hours apart the following day in the plume of another smaller prescribed burn confirmed this conclusion.

So, it seems, once smoke has been formed at the fire, and the very early clumping together of particles has taken place, then the smoke column ages little as it drifts downwind. Little oxidation or evaporation occurs—at least not during the first few hours. Furthermore, as the smoke spreads out, the concentration of particles in the bulk of the plume gradually falls, which must progressively decrease the chances of the particles colliding and sticking together.

Thus, the researchers conclude, the answer to the question about where the smoke finally goes seems clear — it must drift in the atmosphere until washed out by rain. Possibly oxidation and evaporation of the smoke's more volatile constituents may cause some of it to vanish, but these processes will have their effects over periods of several days or weeks rather than over a few hours.

Direct observations of the smoke palls resulting from bushfires in northern Australia during the dry season certainly appear to bear this conclusion out. Such palls may last for weeks on end.

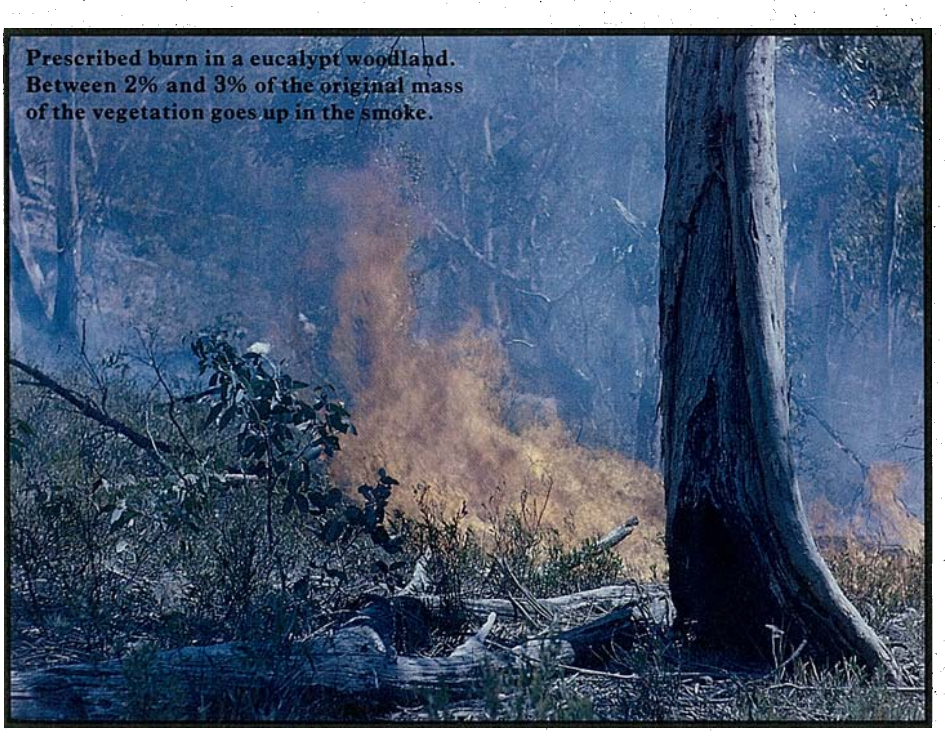
Although such low visibility may be accepted in the outback, people in more-populated areas won't tolerate it.

If the smoke ages little in the hours following its formation, then it should be possible to predict the visibility in any part of the smoke plume. To do this it's necessary to know the amount of smoke likely to emanate from a prescribed burn of a forest, the sizes of the particles making up that smoke, and the atmospheric conditions.

As mentioned earlier in this article, studies in Australia and overseas have shown that the smoke particles from bushfires usually have a diameter of about one ten-thousandth of a millimetre. The research of the Bushfire Section revealed that during a prescribed burn between 2 and 3% of the original mass of vegetation burnt goes up in the smoke. So, knowing the wind speed, the total fuel consumed during a prescribed burn, and the area of country affected by the smoke should make it possible to calculate the effect of the burn on the visibility.

Dr Vines and Mr Packham have now developed a simple model that will enable such a prediction to be made.

They regard this model as rather rough, since it contains several gross over-simplifications. For example, it assumes that the topography isn't important, and that the smoke is uniformly distributed both across the plume and vertically within it. (In practice, the smoke gradually becomes concentrated in the top of the plume as it blows downwind.) Even so, the researchers point out, as the model is only intended to predict the least visibility likely to be encountered, it really doesn't matter if you can actually see twice as far. For a low-flying aircraft, such an error will provide an additional safety margin.



Prescribed burn in a eucalypt woodland. Between 2% and 3% of the original mass of the vegetation goes up in the smoke.

More fires, more smoke

Inevitably, times will arise when country areas are covered by smoke from more than one fire. As it happens, the effect of the smoke from one fire just adds to the effect of another. So likely falls in visibility can be calculated for each individual fire at any location and then added.

Similarly, after burning operations have been going on for some weeks, large tracts of country may be covered by a smoke haze. Direct observation can give some estimate of how much this haze reduces the visibility, but, as the CSIRO researchers point out, it should be possible to calculate it — provided the total fuel consumed during the burning program is known.

Although such background hazes nearly always contain low concentrations of smoke, they often cover many thousands of square kilometres, and may reduce the visibility considerably. According to the researchers, it is rarely possible to see more than between 7½ and 15 km in the Northern Territory at the height of the burning season between July and September.

Although such low visibility may be accepted in the outback, it is interesting that people in more-populated areas won't tolerate it. Experience has shown that city people will put up with a smoke haze if they can see 15 km, but they will not do so if their range of vision is reduced to 7½ km.

More about the topic

Properties of bushfire smoke: the reduction in visibility resulting from prescribed fires in forests. D.R. Packham and R.G. Vines. *Journal of the Air Pollution Control Association*, 1978, **28** (in press).

Further studies of the nature of bushfire smoke. L.F. Evans, N.K. King, D.A. MacArthur, D.R. Packham, and E.T. Stephens. *CSIRO Division of Applied Organic Chemistry Technical Paper* No. 2, 1976.