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Fires from hell

In some countries, extinguishing underground fires could do more to tackle global warming than anything else. But it's easier said than done, as Eugenie Samuel discovers

JOHANN G. GOLDAMMER

DAVID AUSTIN

Smouldering fires in a shallow coal seam (left) have often set Indonesia's forests ablaze (below)

"Protracted and ultimately unsuccessful attempts to put out underground fires are repeated year after year around the world"

AS HE picks his way across a dense forest floor, Alfred Whitehouse's nose is assailed by a biting, sulphurous smell. There are no flames or smoke in sight. For miles around there's nothing but thick Indonesian rainforest. But from the smell, the geologist reckons he must be right on top of the fire. For here, just a few metres below his feet, a coal seam is blazing.

Underground coal fires like this rage at various locations all over the world. The US has several dozen, most started by people burning rubbish in abandoned mines. Other mine fires rage in India, China and Australia. But underground coal fires in Indonesia are among the wildest and hungriest on Earth.

Indonesians are all too familiar with uncontrollable fires. For months during 1997 and 1998, its cities choked under clouds of smoke and haze as millions of hectares of forest burnt. And the fires have returned with a vengeance this year (*New Scientist*, 17 August, p 8). The majority of these fires are started by loggers, but many occur in remote, uninhabited areas, and begin on lightning-free days with not a cloud in sight. Researchers have begun to realise that coal seams burning just beneath the surface could be to blame. And Whitehouse, who is employed by the Indonesian government, is leading a new effort to protect the forest by stamping out these underground fires once and for all.

Taking on and defeating a blazing seam is no mean feat. These fires can burn anywhere between a metre below the surface to 10 metres down and can extend for tens of kilometres. Perhaps the most famous coal seam fire in history ignited in 1961 at Centralia, Pennsylvania, when someone decided to burn some rubbish in an old coal pit. The fire lit a coal seam that stretched for many kilometres. Over the next few years, the town authorities tried pouring water on the fire, blocking off vents with concrete and even excavating the burning coal. As costs rose to millions of dollars, the decision was taken to relocate the town's 1100 inhabitants.

Today Centralia is a ghost town. Researchers expect the fire to continue burning for centuries. And this story, of a protracted and ultimately unsuccessful attempt to put out an underground fire, is repeated year after year, all around the world. In 1999, for example, geologists on an Ute Indian reservation in Colorado decided to attack a new coal fire 1.4 kilometres long that was undermining local forest and threatening a road. The Utes spent almost a million dollars pumping a styrofoam-concrete mixture into vents that were feeding the fire, aiming to break it up into small chunks and suffocate it bit by bit. The tactics seemed to work. Then, a few weeks later, a new vent opened several hundred metres away and they were back to square one.

This experience is typical for those who take on fires in coal seams. The flames suck in air not only through large cracks that can open in the ground, but also between the pebbles in gravel soils. So trying to cut off the air or cool the rock by pouring water into a vent will work only if you're very lucky. Usually the fire will continue to smoulder. And as soon as a new crack opens, back come the flames. "I don't think there's one documented case where this [technique] has worked," says Whitehouse.

In the early 1990s, Whitehouse managed a firefighting team based at the Office of Surface Mining in Washington DC that extinguished several persistent coal fires across the US. With all their experience, Whitehouse and his colleagues came to the conclusion that any attempt to suffocate an underground fire or cool the rock around the coal to prevent it igniting was doomed to failure. The team had learned the hard way that when a fire is burning intensely, the best strategy is to give up on whatever has already caught fire and create a firebreak in the path of the flames.

By excavating the coal beyond the edge of the fire, the idea is to cut the blaze off from the rest of the seam and prevent it spreading. The strategy worked against many US coal fires, particularly in mines where the location of the seam was well documented. But still there were problems. Sometimes not enough coal was ▶

removed and the fire would leap the gap. "We put out a lot of fires only to find suddenly that they weren't out," says Whitehouse.

Hearing of his successes, in 1997 the Indonesian government asked Whitehouse to take a look at its own problem. At that time, there was no programme to deal with fires in coal seams. Just as in the US, it was considered cheaper to move houses and people than to take on a fire that no one could see. But a new global initiative to set national targets for tackling global warming – the Kyoto Protocol – was making the Indonesian government take a fresh look at the nation's carbon dioxide emissions. It realised that putting these fires out could be easier and more effective than cutting factory or car emissions.

Save the bears

Whitehouse's first task was to estimate the scale of the country's problem. He began to work with ecologists at the Sungai Wain Protection Forest in East Kalimantan. During the 1997-98 El Niño drought, more than half of the forest's 10,000 hectares had burnt. This almost wiped out a population of endangered Asian sun bears, and a population of orang-utans that were reintroduced to the wild there in 1992. Surveys initiated by Gabriella Fredriksson, a sun bear ecologist working for the Dutch forestry research group Tropenbos, had already located 73 coal fires, as many as there are in the entire US. Whitehouse realised that scaling up this figure would bring the national coal fire count to around 100,000. "I often lie about [this] because I don't want to scare people," says Whitehouse. These fires may produce more CO_2 than all the power stations and cars in Indonesia put together.

Within a few days of arriving in Jakarta, Whitehouse had his first call. A few years earlier, a smoking vent had opened up near a house in East Kalimantan. Arriving there, Whitehouse could make out the path of the fire by a telltale wake of dying vegetation, killed by sulphur dioxide, methane and other noxious combustion products seeping out of the soil. The owner had been trying to halt the fire's progress towards his house for two years. He had capped obvious vents and pumped in a great deal of water. However, this was a very advanced fire. By taking measurements of ground temperature, Whitehouse found the fire was arc-shaped, moving away from the point at which the seam had first caught light. So he excavated coal in a wider arc ahead of the fire, carefully removing any coal that was at even a slightly elevated temperature. It worked. Today the firebreak is filled in and there's an orchard atop where the fire once raged.

All this required was a shovel, a long thermometer for measuring temperatures a few metres down, a pump to spray water onto coal that was too hot to dig out and a lot of muscle power. But Whitehouse has also realised that any attempt to quench similar blazes will fail unless the diggers understand how underground fires advance.

Fortunately, coal fires in Indonesia conform to a basic pattern. The seam almost always comes to the surface in an outcrop on a hillside (see Diagram). It is here that the coal can be ignited by forest wildfires or fires set by unsuspecting loggers. As the seam burns, it excavates a cavern underground in an arc, moving away from the outcrop. And although the fire may begin to run out of air, the unsupported ground above can easily shift or collapse, creating cracks which fan the flames again. The only way to stop it is to dig out the coal in an arc ahead of the fire.

Of course it's easy to convince people to tackle a fire that's threatening their homes. It's not so easy to convince the authorities it's worth tackling remote fires in the middle of uninhabited forest. One day, while examining

Digging a firebreak (right) put out a fire that had been smouldering for two years close to a house in East Kalimantan. Fires below ground also threaten the region's orang-utans (far right)

a coal fire in the Sungai Wain Protection Forest, Whitehouse saw a cinder from a coal seam fly out and hit some brush, which caught fire. He quickly stamped out the fire, averting what could have become a devastating conflagration. But it made him think: were coal fires responsible for the mysterious ability of forest fires to come back year after year, even in areas with no human activity or lightning. In the long winters when the forest is soaking wet, the fires could be surviving underground.

Whitehouse was not the first to have this idea. In 1987, Johann Goldammer from the University of Freiburg in Germany was picking his way through Bukit Soeharto National Park in East Kalimantan, looking for charcoal evidence of ancient forest fires. What he found instead was a real live forest fire started minutes before by sparks from a burning coal seam. For Goldammer, who was interested in the evolution of ancient rainforest, this provided a stunning insight into the history and evolution of the most ancient


JOHANN G. GOLDAMMER

SCORCHED EARTH

During the last ice age, fire may have been an even more important feature of life in the rainforest than it is today. With much of the world's water trapped as ice, the planet's climate was much drier. The rainforests retreated to isolated refuges, along rivers or deep protected valleys. Between these lush oases, lighter forest or thin brush grew.

While travelling the Indonesian rainforest, fire ecologist Johann Goldammer of the University of Freiburg in Germany found layers of charcoal, the remnants of ancient forest fires. Radiocarbon dating suggests the fires were burning about 18,000 years ago – around the time of the last ice age.

Goldammer also came upon layers of clay baked as hard as it is in a kiln, the result of ancient coal fires burning like ovens. To date the clay, he approached an archaeological laboratory that used a thermoluminescence technique – which measures the emission of light from radioactive isotopes when they're heated – to date ancient pottery. The dates ranged between 2000 years ago and the last ice age.

Many of the charcoal deposits lie in corridors between rivers and deep valleys, suggesting that the light brush occasionally caught fire. In corridors with coal seams, says Goldammer, there seems to have been an ignition source that started fires very often, perhaps every year. This, thinks Goldammer, would prevent or reduce the spread of plant and animal species between isolated groves, setting the scene for thousands of years of divergent evolution. "Maybe this is why the rainforest is so biologically diverse," he says.

ANDY ROUSE / NHPA

"Fires in Chinese coal seams could be burning up to 100 million tonnes of coal per year, far more than the country burns deliberately"

rainforests on Earth (see "Scorched earth").

But for Whitehouse, the same insight – that coal fires could light forest fires – had practical consequences. In 1998 he began his first education programme, working with ecologists to figure out how to extinguish the fires. Together with local people they snuffed out 65 coal seam fires that had started that year. So far, that work appears to be standing them in good stead. Despite the influence of the weather system El Niño this year, which has dried the rainforest and led to an early start to the fire season in the western US and in Indonesia, Sungai Wain remains fire-free so far. "Our problem is neighbouring areas which have the same coal layer conditions," says Fredriksson. "There's a large logging area and I am quite worried their coal fires will cause a problem for us."

Extending the fire-extinguishing programme nationally is a daunting prospect. With funding from the US Office of Surface Mining, Whitehouse has now helped to train over 200 Indonesians in how to put out fires in coal seams. "We have [trained] people from local and county governments, from mining and timber companies and NGOs," says Asep Mulyana, a geologist working for the Indonesian Ministry of Mines and Energy and on secondment with Whitehouse. And now the expertise exists, Mulyana hopes mining and logging industries will tap into it. "Before Alfred's work started, people here didn't think it was possible to put these fires out," he says.

Funding the fight

The next step will be political. Mulyana and others are hoping that a small proportion of the taxes from coal mining can be set aside every year to fight coal fires, especially on the islands of Sumatra and Borneo where forest fires are a particular problem.

But funding for pumps, shovels and training courses may not be enough. Most fires burn in such remote places that no one complains about or even reports them. Fortunately, help could come from above. Goldammer is now working with a team at the German Aerospace Centre that launched a satellite called BIRD in 2001. He hopes to use its thermal cameras to image the coal fires in Indonesia at a much higher resolution than has been possible so far. Its first images show hot spots that match the known locations of coal fires on the ground. In the long term, however, Goldammer hopes that maps of more remote areas will enable him to calculate the rate at which fires in coal seams trigger forest fires in hot summers. This data could provide the impetus for government or local officials finally to begin extinguishing the fires.

Other eyes in the sky have shown that Indonesia isn't the only country with this problem. In 1999, geophysicist Anupma Prakash and colleagues from the International Institute for Geo-Information Science and Earth Observation in Enschede, the Netherlands, reported on their survey of underground coal fires in China using an infrared detector on NASA's Landsat satellite. Their results confirmed previous work that suggests that fires in Chinese coal seams could be burning up to 100 million tonnes of coal per year, far more than the country burns deliberately. Here too, Whitehouse's techniques could prove useful. "There's a clear financial interest to look at this," says Prakash. One of China's most precious natural resources is literally going up in smoke.

In the meantime, Indonesians have a chance to wrest back control of their own environment. And whenever Whitehouse needs to convince a top minister in the government or a visiting World Bank official that funds for coal seam firefighting can be effective, he takes them down to meet Umar, the owner of the house in East Kalimantan, and sits down with them in the orchard where the fire once burnt. "It's the kind of testimonial you can't pay for," says Whitehouse. "And we've made a friend for life." ●

FIGHTING FIRE DOWN BELOW

Bringing a fire in an Indonesian coal seam under control by digging a firebreak