CRISIS COUNSELLORS

Volcanic eruptions, oil spills and bacterial outbreaks all land in the laps of government science advisers, and put them to the test.

BY ALEXANDRA WITZE, LAUREN MORELLO & MARIAN TURNER

As a population biologist, John Beddington spent most of his career studying fisheries rather than worrying about volcanoes. But then came April 2010, when Beddington — the UK government's chief scientific adviser — found himself having to figure out not only how to pronounce Eyjafjallajökull, but also what to do about the eruption of the Icelandic volcano.

In the small hours of 14 April, the volcano had gone from its previous state — picturesquely spitting out lava — to violently spewing plumes of ash high into the atmosphere. Winds were blowing to the south and east, where the fine ash presented a threat to Europe's busy commercial airline routes. Suddenly scientists were scrambling not only to understand how much ash the volcano was generating, but also how it was spreading through the atmosphere and how much of a risk it presented to aircraft. So Beddington got a call at his Cotswolds home summoning him to 10 Downing Street. "I sort of dusted off my brain and went into the meeting," says Beddington, who is now at the University of Oxford.

In the first week of the crisis, authorities progressively closed airspace where the volcanic ash was billowing. Ultimately more than 300 airports were shuttered across Europe, stranding some 8.5 million passengers and causing major economic losses to the airlines and businesses that depend on them. Each country made the decision about its own airspace, which put Beddington front and centre of helping UK officials figure out what to do.

When scientists enter government in the role of a scientific adviser or as the head of a science agency, they need to be prepared for the unexpected. Some of their most crucial contributions come during crises, a theme that will be explored on 28–29 August at a global summit of science advisers in Auckland, New Zealand. On the eve of that meeting, *Nature* takes a look at how such officials performed during the Eyjafjallajökull eruption, as well as the 2010 oil spill in the Gulf of Mexico and a deadly disease outbreak in Europe the following year.

These cases show that science advisers have key roles in a crisis, especially in disseminating clear, reliable information to government leaders and the public. But at times, they struggle with the demands presented by disasters: rare events can take them by surprise, bureaucracy

The eruption of Eyjafjallajökull in Iceland stranded millions of people around the world.

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can strangle their attempts to respond and they often cannot keep pace with the evolving situation. "We have to form a view about advice for the government," Beddington says. "And we have to do that on a fairly quick time scale."

FLIGHT RISK

After leaving his meeting with the prime minister, Beddington began to round up a panel of volcanology and meteorology experts to form an Eyjafjallajökull-focused Scientific Advisory Group for Emergencies (SAGE), the UK government's main mechanism for gathering technical advice and passing it along to decision-makers in crises.

The SAGE concept was born in the wake of the 1990s spread of bovine spongiform encephalopathy, or 'mad cow' disease. Beddington was the first UK chief science adviser to gather a SAGE group together, during a 2009 influenza pandemic. Because of that experience, he says, when the Eyjafjallajökull crisis began, "I knew the sort of people I'd need".

The SAGE volcanic ash group met for the first time on 21 April, after London's Heathrow airport — the world's busiest — had faced the cancellation of more than 97% of its flights for five days straight. The group included Sue Loughlin, a volcanologist at the British Geological Survey in Edinburgh, who did her PhD on Eyjafjallajökull and had served in Montserrat, in the West Indies, during a deadly eruption there in 1997. Loughlin and others supplied basic information about the volcano's geological history and the pace of the ongoing eruption.

Yet the ash cloud, and the crisis, moved faster than the advisory group. Pressured by airlines that wanted to resume flights, Europe's transport ministers had on 19 April quickly brokered revised operational guidelines. Planes were in the air again even as SAGE began to meet.

After the initial eruption had quietened, the volcano continued to spew low levels of ash, and nobody knew whether the activity might pick up again. Three more times over the next two months, Beddington convened SAGE to assess technical details about the eruption and the likelihood of more to come. Among other things, the group explored whether a nearby volcano named Katla might also erupt, as it has in the past along with Eyjafjallajökull. The advisers passed that information to the Cabinet Office, which used it to develop scenarios for future volcanic-ash emergencies.

SAGE also pushed government departments to assess the risk of future, larger volcanic eruptions. In 2012, the Cabinet Office added Icelandic eruptions to Britain's National Risk Register, the official list of possible events that could disrupt society. "I had not thought of it at all before then," says Beddington. "It was very embarrassing." The Cabinet Office is also working up a detailed scenario for how to respond in the face of an eruption that could spew sulphur and other toxic gases across Britain, as the Icelandic volcano Laki did for eight months in 1783–84.

David Alexander, a risk expert at University College London, says that the Eyjafjallajökull experience improved some aspects of disaster response in the country. The International Civil Aviation Organization, for example, has updated and clarified its guidelines on how much ash planes can fly through safely. And the UK Met Office has fine-tuned its atmospheric models for predicting the spread of dry ash through the air.

But nearly all parts of the government took much too long to respond to the crisis, Alexander says. And he notes that even now, no coordinated plan exists to manage alternative transportation, such as the ferries, trains and taxis that became overloaded in April 2010. "There is still no adequate way for dealing with millions of stranded people," Alexander says.

Before Beddington left office in 2013 — replaced by Mark Walport — he activated the SAGE mechanism once more, this time to provide advice about whether to evacuate the British nationals in Japan after the 2011 meltdown at the Fukushima nuclear power plant. SAGE modelled how radioactive material might spread and concluded that the risk of being exposed to radiation was relatively modest. In the end, the government provided iodine tablets as a precautionary measure but told its nationals they could stay put.

And just in case, Beddington also ran some tabletop exercises for a major space weather event that could blow out power grids as well as other events so alarming that he prefers not to even name them. "If any of these instances had happened," he says, "we'd have been in position to pull a SAGE team together."

DEEP TROUBLE

Even as the volcanic ash cloud was spreading over Europe, science officials in the United States were struggling with their own crisis, one of the biggest ecological disasters in the nation's history. It all started just after 9 p.m. on 20 April 2010, when an engineer aboard

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During the 2010 Gulf oil spill, President Barack Obama met with scientists Steven Chu (far left), Jane Lubchenco and John Holdren, and coast guard commandant, Thad Allen.

the BP Deepwater Horizon oil rig in the Gulf of Mexico noticed an odd vibration. Minutes later, the rig exploded, killing 11 men and beginning a months-long effort to stanch the flow of oil from a damaged well on the sea floor and avert an environmental catastrophe.

By the time the leak was first plugged in early August 2010, an estimated 4.9 million barrels had gushed into the gulf — surpassing all previous marine spills — and in so doing had put US President Barack Obama's vaunted first-term science team to its toughest test, one for which it has received mixed marks.

Deepwater Horizon was a daunting disaster, with crude oil gushing from a reservoir of unknown size at a depth of 1,500 metres. But for more than a month after the blowout, the administration vastly underestimated the amount of oil flowing into the gulf — a mistake that hampered efforts to cap the leaking well and undermined public confidence in the president's response to the crisis. Key science officials, including presidential science adviser John Holdren, were slow to correct the erroneous estimates — even as academic scientists argued that the spill was orders of magnitude larger than BP or the government had publicly stated.

On paper, the crisis seemed tailor-made for the all-star group of scientists that Obama had assembled after he took office in 2009. Holdren, a physicist, directed the White House Office of Science and Technology Policy (OSTP), while Jane Lubchenco, a marine ecologist, helmed the National Oceanic and Atmospheric Administration (NOAA). Geophysicist Marcia McNutt had stepped in to lead the US Geological Survey (USGS). And the Energy Department boasted Nobel-prize-winning physicist Steven Chu as its leader.

Holdren says that the government sought help from outside scientists within hours of the explosion. But in many respects, Obama and his science team moved too tentatively. It was not until 19 May — almost a month after the blowout — that the administration assembled a group of scientists and engineers, headed by McNutt, to revise the controversial flow-rate calculations. The oil flow was extremely hard to estimate because there was no direct way to measure the well's output, and industry and research scientists disagreed about how best to do it.

NOAA had long maintained that the flow was about 5,000 barrels a day, but independent scientists examining satellite imagery of the growing oil slick and BP video of the undersea well had argued that the actual output lay between 25,000 and 100,000 barrels per day. "The estimates that kept coming up formally from the agencies were to me just too low," says Kate Moran, an oceanographer then working as a senior policy analyst at the OSTP. That error created problems for BP when it tried to cover the gushing wellhead with an iron dome, because the cap was unable to contain the volume of escaping oil and gas.

It took until 27 May for the committee assembled by the administration to determine that the flow rates determined by NOAA and BP were indeed too low. The group estimated that 12,000–19,000 barrels of oil were spilling into the gulf each day. Ultimately, the government would arrive at a much larger figure — 62,000 barrels a day immediately after the blowout, dwindling to 53,000 barrels a day in August, before a temporary seal stopped the flow.

"The most difficult part about it was trying to understand what we were getting from BP, and whether we really understood the possible sources of error," says McNutt, who arrived at BP's oil-spill operation centre on 6 May and remained for the duration of the crisis. "It actually took some time, and maybe too much time, to realize the magnitude of the problem," says Larry Mayer, an oceanographer at the University of New Hampshire in Durham. He argues, however, that the response quickly improved in mid-May, when Holdren and other officials met with scientists from some of the country's top oceanography programmes, seeking access to equipment such as remotely operated underwater vehicles and ways to track the oil as it spread in a plume below the surface.

That plume was a source of great grief for NOAA chief Lubchenco, whose agency was mandated by US law to assist the Coast Guard in tracking the oil's path through the Gulf of Mexico and monitoring its effects. In mid-May, academic researchers reported finding masses of microscopic oil droplets 1,000–1,400 metres below the ocean surface, spreading outward for tens, possibly hundreds, of kilometres from the leaking wellhead. Almost immediately, Lubchenco issued a statement calling reports of those findings "misleading, premature, and in some cases, inaccurate", drawing a wave of criticism from oceanographers who felt that she was unduly dismissive of important evidence.

"That was truly a head-slapping moment for me as an oceanographer," says Ian MacDonald from Florida State University in Tallahassee. It took another 22 days before NOAA acknowledged the presence of the plume — a delay that fed mistrust of the agency by outside scientists.

By contrast, McNutt and Chu drew praise for their actions during the crisis. While McNutt helped to determine the amount of oil leaking into the gulf, Chu worked to stop the flow. He arrived in Houston on 12 May, accompanied by distinguished scientists recruited with Holdren's help, including some from JASON, a storied panel that advises the government on issues such as defence and energy. They and others quickly began challenging BP for more and better data about the state of the well. Chu convinced the oil company to monitor the wellhead using γ-ray imaging as well as temperature and pressure gauges, which provided the first direct measurements of the still-flowing oil.

Finally, on 19 September — 150 days after the initial explosion and well blowout — the Coast Guard declared an end to the disaster after engineers inserted a cement plug to permanently seal the well. Four years later, disappointment still lingers among many scientists about the way in which the Obama administration handled Deepwater Horizon. Stopping the oil's flow "was a huge effort, and people worked heroically and tirelessly", MacDonald says. But, he argues, the scientists leading government agencies should have acted more quickly and provided better information about the extent and nature of the spill. "At many critical junctures in the process," he says, "the government was on the wrong side of history."

> *"AT MANY CRITICAL JUNCTURES IN THE PROCESS, THE GOVERNMENT WAS ON THE WRONG SIDE OF HISTORY."*

OUTBREAK

A year after the Deepwater Horizon spill, doctors in Hamburg, Germany, put out a call for help. On 19 May 2011, three children at a city hospital were battling haemolytic uraemic syndrome, a life-threatening condition caused by a severe gastrointestinal infection with the bacterium *Escherichia coli*. Worried that the outbreak could spread, Hamburg health officials contacted the Robert Koch Institute (RKI) in Berlin — Germany's federal agency for disease control and prevention.

When three RKI epidemiologists arrived in Hamburg the next day, it was clear that something unusual was going on. Several other cases, including some in adults, had popped up at hospitals around the city and reports soon came in from other regions. What followed was Europe's worst recorded outbreak of *E. coli* infection. By the time the outbreak was declared over, some two months later, more than 3,800 people had developed acute gastrointestinal infections. Of those, 845 had progressed to HUS, and 54 had died. The correct source of the infection — fenugreek seeds from Egypt — was not identified to the public until 5 July.

Reinhard Burger, president of the RKI, says that the outbreak "was a good example of how

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rapidly a new threat can appear and develop and affect the population". The event also illustrated the problems that can emerge when scientists at multiple agencies — reporting to different levels of government — respond to a public-health emergency.

The RKI's most pressing task was to identify the strain of bacterium that was causing the infection and then where it came from. *E. coli* infections are typically caused by contaminated foods, and the epidemiologists began by interviewing patients about their recent diet. "We knew within the first two days or so that the usual suspects — fresh milk and raw-meat products — were not the problem," says Burger. The only thing all patients seemed to have in common was that they had eaten salads containing fresh tomatoes, cucumber and lettuces, in northern Germany. On 25 May, the RKI, which reports to the federal health ministry, issued a joint statement with the federal institute for risk assessment (BfR), saying that these vegetables were associated with increased risk of infection.

Science advisers at the RKI say that the various federal agencies responsible for disease control and food safety worked together smoothly to assess the risks and communicate them to the public. But the coordination between them and agencies that reported to state governments was not nearly as efficient. As cases emerged throughout Germany, the chain of orderly communication cracked. The worst blunder came on 26 May, when Hamburg health senator Cornelia Prüfer-Storcks announced that the Hamburg Institute for Hygiene and Environment had discovered enterohaemorrhagic *E. coli* (a pathogenic class of *E. coli*) on Spanish cucumbers. But she had not consulted the RKI before making that statement. And tests a few days later revealed that the bacteria on the suspect cucumbers did not belong to the same strain found in patients.

The ongoing uncertainty about the source of the bacteria led to trade restrictions and large economic losses, particularly in Spain, where farmers found themselves unable to export cucumbers and other suspect produce. The European Commission eventually issued a €227-million (US$302-million) payout to farmers from several countries.

Burger says that the Hamburg statement "damaged confidence in public announcements". The problem was compounded by the public's increasing hunger for information while epidemiological investigations were failing to turn up more-specific leads. "I was facing the media every day, but sometimes we had nothing new to say," he says.

Looking back, health officials say that some technological improvements could help. For instance, Burger says that using genetic sequencing rather than the current culture-based diagnostic techniques might have helped physicians to recognize the outbreak more quickly.

Local authorities in Germany incorrectly identified Spanish cucumbers as the source of deadly *E. coli* during an outbreak in 2011. Reinhard Burger, who heads the nation's federal agency for disease control and prevention, and other health officials worked to clear up the confusion.

The response was also hampered by a complicated reporting chain: when physicians confirm a case of a disease, they report it to local health authorities, who forward it to the RKI. Before the outbreak, that process could take up to 16 days. A change to the law last year means that reports must now reach the RKI within 5 days. But the notifications can still trickle in by phone, fax or e-mail. The federal health ministry is therefore developing an electronic system to provide faster and simultaneous notification for local and federal authorities.

Such a system would not bypass the problem that the RKI can act only at the request of state agencies — a rule that some feel should be changed. "When there is the impression than an outbreak is affecting more than one state, the RKI should have the right to start investigations on its own," says Ulrich Frei, medical director of the Charité hospital in Berlin, which handled several cases. "Health is one of only a couple of topics in which the German states still have much authority, and they're not very willing to transfer this to the federal level," he says.

As with natural disasters and human-caused crises, the outbreak points out the benefits of high-level coordination during emergencies. Peter Gluckman, New Zealand's chief science adviser, grappled with this issue when an earthquake levelled much of Christchurch in 2011. In the aftermath, competing scientific experts debated future risks in the media in a way that spurred confusion among government officials and the public, says Gluckman. His office spent weeks trying to get scientists to provide clear information about existing threats and uncertainties. A crisis demands scientific coordination, he says. "Often it is made worse by inconsistent communication". ■ SEE EDITORIAL P.347

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