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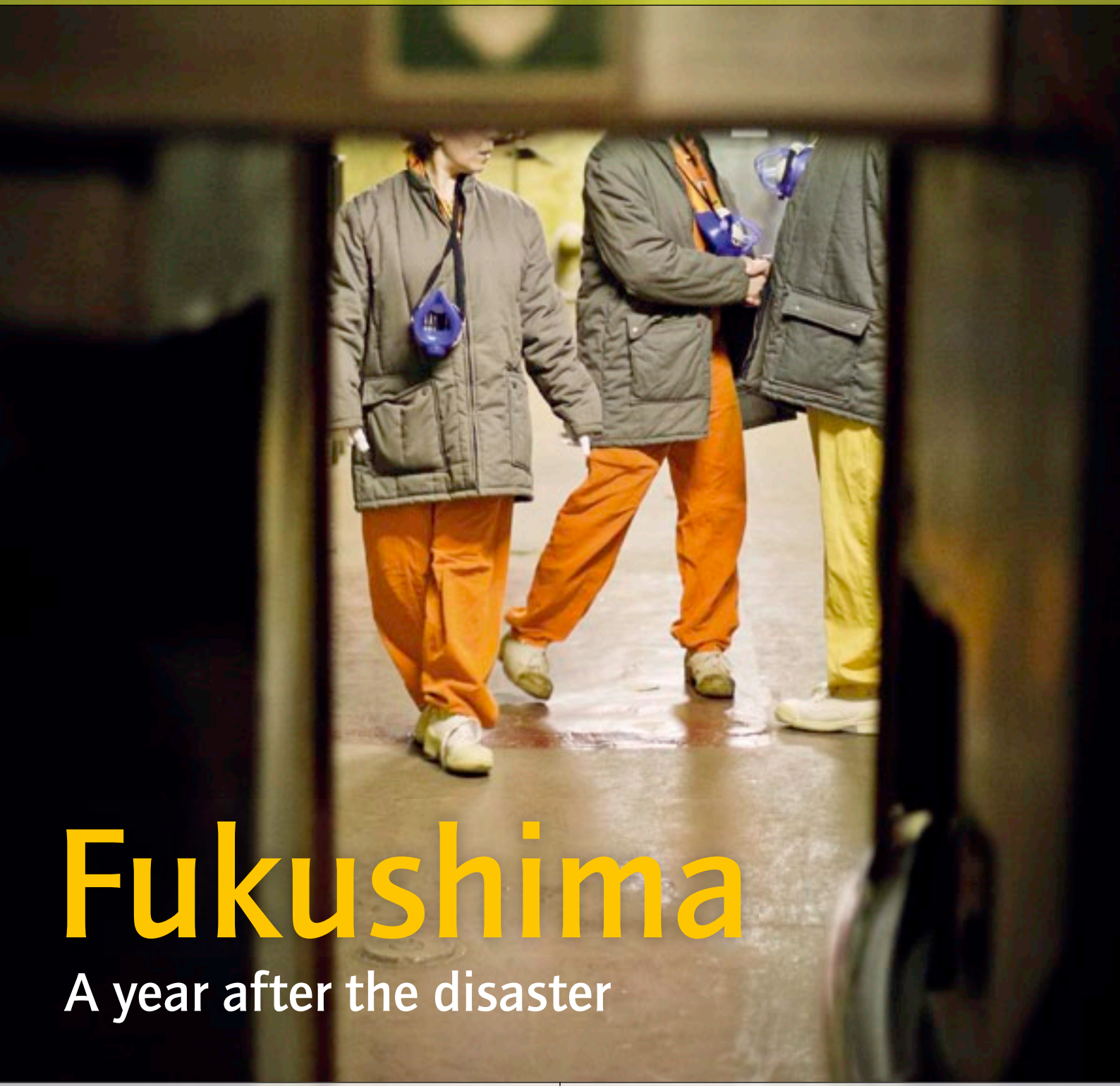


Fukushima

A year after the disaster

Interview
Professor Dr. Rolf Michel, radioecology expert

Discussion
The lessons learned from Fukushima

Fukushima – and Fukushima again

2011 was an eventful year. Things began in March with an incident that drew the attention of the whole world to Japan: on top of the combined natural disasters of the earthquake and tsunami, and triggered by them, came the worst nuclear accident since Chernobyl. Core melt occurred in three standard reactors, in an advanced industrialised country – a fact that many people found deeply troubling and that ultimately spurred German politicians into action. In Germany we are now seeing a shift in how the risks of nuclear energy are assessed and a transition in energy policy.

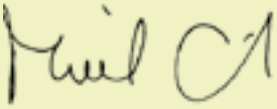
The ways in which the energy policy landscape has changed in Germany since Fukushima has been described in previous issues of eco@work. There is still much to be done to make the transition to sustainable energy a reality, but more about that in future issues.

One year on, the current issue that you have in your hands again focuses on events in Fukushima. What happened in the reactor blocks of the Fukushima Daiichi nuclear power plant? What new information about the radiological situation in the area around the plants have the experts acquired since then? What challenges face those responsible for making the damaged plants safe, recovering the nuclear fuel and dismantling the ruined buildings?

In the wake of Fukushima, Germany amended its Atomic Energy Act nearly a year ago, specifying a shorter life span for its nine newer nuclear power plants and the rapid shutdown of eight older plants. This is because a tsunami is not the only event that could trigger a major core melt accident. Other major incidents involving flood, earthquake or a plane crash could result in core melt at any reactor, as could unnoticed maintenance errors or design faults or complete failure of the power supply to the nuclear power plant's safety systems.

A glance at other countries shows that they have responded in different ways. Some are phasing out nuclear energy, although more slowly than we are; others intend to continue as though nothing had happened. All plants are undergoing a "stress test", but what does that mean? This edition of eco@work sheds light on these and other matters.

We hope you enjoy reading this issue and look forward to your questions and feedback.



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Content

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"I should like to urge the authorities to release existing data."

He is regarded as an authority in his field. For 26 years Professor Dr. Rolf Michel was head of the Centre for Radioecology and Radiation Protection at the University of Hanover. For 16 years he has also been a member of the German government's Commission on Radiological Protection, and he chairs the country's nuclear emergency response unit. At the request of the German Environment Ministry, Rolf Michel travelled to Tokyo in July 2011 to assist the German embassy. He talked to eco@work about his experiences.

Professor Michel, what was your task in Japan?

The main task was to assess the radiological situation and to translate the physical and chemical data into tangible appraisals. A key aspect was evaluation of the data on contaminated food. And of course I also spoke to concerned members of the public and answered their questions.

You quickly became an important contact point. What was the most disconcerting thing about that?

The large number of scientifically untenable scaremongering messages, which circulated in particular in the social media. This was completely irresponsible and fuelled the fear. I then tried to get the facts across to people who had been frightened by these messages. This gave them an objective basis that they could use to judge whether or not they needed to be anxious.

How do you assess the radiological situation now?

Outside Fukushima prefecture, exposure to radiation is not a big issue. Within the prefecture and beyond the 30-kilometre zone there is a swathe towards the north-west with high local dose rates, in some cases in excess of four microsieverts per hour. Under German standards, such areas should no longer be inhabited. The Japanese authorities are trying to reduce the local dose rate through decontamination, but it remains to be seen how successful that will be.

By what routes are people today most at risk of exposure to radiation?

As things stand at present, for someone in Fukushima prefecture the main risk is external exposure to radiation from caesium 137 and caesium 134. By contrast, internal exposure by eating contaminated food seems to be fairly moderate. But I say that with reservations, because we have only very scanty information. Japan is very reluctant to release figures for dose rates in relation to people. I should like to urge the authorities to release existing data.

What has been the effect of Fukushima on the work of the German Commission on Radiological Protection?

The most important question is: Are our emergency management systems sufficiently well prepared for a comparable accident? That doesn't apply only to radiation protection per se. For example, we have a problem with our information systems. They are mostly in German. We must adapt them into English. If the worst happens, the international community must have quick and straightforward access to relevant data.

What have you personally found particularly moving about Fukushima?

I am shocked at how quickly we have forgotten those who died or were injured by the earthquake and tsunami. Our thinking about the technical situation and about the victims is completely out of balance.

Research into radiation protection in Germany is not in a healthy state. Professorships are not filled when they become vacant and research funding has been repeatedly cut in recent decades. Why is that a big mistake?

We are witnessing a regrettable decline in this area. I should like to make the point quite plainly: Even if Germany phases out nuclear energy as planned, for at least the next two generations we still need well-trained people with the necessary skills to deal with the management and dismantling of power plants. And we need skills to handle the many other applications of radiation.

What then does radiation protection research do that related sciences – such as biology or medicine – cannot cover?

There is currently a welcome push to establish a radiation research skills network that brings a whole range of disciplines together. But without the specific discipline of radioecology it is not possible to evaluate radiological accident scenarios, contaminated sites and the consequences of final disposal.

Thank you very much.
The interviewer was Katja Kukatz.

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Talking to eco@work:
Professor Dr. Rolf Michel, chairman of the emergency response unit of the German government's Commission on Radiological Protection

Fukushima – a year after the disaster

In the history of civil nuclear technology, 11 March 2011 marks another turning point. After a catastrophic earthquake that triggered a major tsunami, the greatest reactor disaster since Chernobyl occurred at the Fukushima Dai-ichi nuclear power plant on the east coast of Japan. With the plant devastated, the mains electricity grid destroyed and the emergency power supply completely out of action, the cooling systems failed, there were three core meltdowns in quick succession and several hydrogen explosions in four neighbouring reactor blocks, while three reactor pressure vessels were destroyed – an event more serious than anything envisaged in nuclear accident scenarios. How could this happen?

Over the past year scientists and scientific institutes around the world – the Oeko-Institut among them – have been seeking answers to this question. Yet many details are still unclear – partly because the failure of measuring instruments meant that very little data relating to the first few hours was obtained, and partly because some actions taken during the event were not fully documented.

Dr. Christoph Pistner, an expert on facility safety at the Oeko-Institut, comments: "The reactors were automatically shut down when the earthquake occurred, and until the tsunami struck the emergency diesel generators and the cooling systems were still working." It is impossible to know for certain whether the plant could have survived the earthquake alone. "The backup systems were certainly working initially," Pistner explains, "but it is not possible to determine beyond doubt whether they would have continued working perfectly for hours and even days and whether it would have been possible to stabilise the plant permanently despite the country's devastated infrastructure."

However, it is clear that Fukushima Dai-ichi was not adequately designed to cope with the tsunami, although it was known that such an event could occur here. The plant was only capable of withstanding waves up to about six metres in height. Yet the waves that struck on 11 March were up to 14 metres high: they flooded large parts of the site including the auxiliary cooling water system, battery rooms and the machine-house basements containing the emergency diesel generators. The emergency power supply failed, rendering inoperable the electrically operated cooling pumps that were a crucial part of the plant's safety systems, vital backup measuring instruments and controls, the emergency lighting, communications technology and more. The disaster was unfolding.

"When all backup systems fail, emergency plans should kick in to save what can still be saved," says Christoph Pistner. "Yet even in favourable circumstances such plans are but a weak substitute for the backup systems, and in the face of the devastation at the site they were totally inadequate." For example, it took an exceedingly long time to replace non-functioning batteries. Instead, workers had to make do with car batteries, which meant that for days even key tasks such as relieving pressure in the reactor could not be carried out. Communication between the plant operator, the authorities and the public was also completely inadequate.

Situation still critical

The accident was under control, declared the Japanese government in December 2011. The Oeko-Institut criticised this announcement as "misleading and inappropriate" and has still not given the all-clear. Tepco has managed to stabilise the power supply, and the reactor pressure vessels and the storage pools are being continuously cooled. Reactor Block 1 now has a makeshift protective covering to prevent the release of radiation and ingress of rainwater. Block 4's cooling pond, which was at risk of collapse, has now been repaired. Yet operating conditions are by no means back to normal. According to Pistner, it is doubtful whether the plant could withstand a further major incident such as another severe earthquake.

The fact is that the primary containments and reactor pressure vessels together with large parts of the reactor buildings have been extensively damaged and so still have the potential to leak. Water is being continuously fed into the reactor pressure vessels through temporary piping. "Because of the fission products that are present, the cooling water is highly contaminated, and it is flowing through gaps in the vessels into the basements of the buildings. From there it is being pumped out, largely decontaminated, and re-used for cooling," explains Christoph Pistner. This is a long way from being a permanently viable, closed-circuit cooling system. "And while the primary containments and reactor pressure vessels remain damaged, it is impossible to set up a closed cooling cycle," says the expert from the Oeko-Institut.

Moreover, there are still contaminated building materials and a great deal of highly radioactive cooling water on the site. Both must be collected; the cooling water must be cleaned or stored in a controlled environment. Yet there are not enough storage tanks for long-term use, and it is uncertain whether the filter systems are technically capable of dealing with such large quantities over an extended period. There is also

a question mark over what is happening in the containments and the reactor cores inside them. Radiation levels are still so high that engineers have been unable to enter. No one knows when it will be possible for them to go in: it might be in two years' time or in ten.

So far the only photographs from within the containments that exist were taken in Block 2 by remote-controlled video camera. All other statements are based on computer simulations. "We don't know how much of the material has melted and where the parts of the former core now are. It's not clear whether, when or how piecemeal removal of the shattered fuel elements and re-solidified core will be able to start", says Christoph Pistner. Tepco estimates that it will be ten years before fuel retrieval can commence. It is due to be completed in 20 to 25 years – in Christoph Pistner's view a highly ambitious goal.

Radiological consequences

The principal radioactive substances that were released in Fukushima, mainly at the start of the accident, were noble gases, iodine 131, caesium 134 and caesium 137. Uranium and plutonium isotopes, on the other hand, were insignificant, since only a very small part of the reactor inventory of these substances was released. Radionuclides escaped in two ways. Some were airborne, because in the initial days the reactors were opened frequently to release pressure. Land to the north-west of the plant was particularly heavily contaminated. But fortunately for the people of northern Japan, favourable wind conditions carried the majority of the radionuclides in the air out to sea towards the east. Other radioactivity escaped into the environment via highly contaminated cooling water, which was uncontrolled as it flowed from the damaged reactors into the sea.

In the initial days after 11 March, the only data detailing which radionuclides escaped into the environment at which particular time comes not from the plant operator but from measuring stations near Tokyo and in Russia and the USA that monitor international compliance with the international nuclear test ban treaty. It was a matter of chance whether and when a radioactive cloud from Fukushima would be detected by a monitoring station. Emergency measures could have been effective only if information on the level and in particular the composition of the radioactivity were rapidly procured. Yet – especially in the early days – the right measuring equipment and relevant readings were not to hand.

Reliable estimates of the quantities and types of released radionuclides have now become available. Today caesium 134 and caesium 137 predominate. Caesium 137 poses a particular problem: it has a half-life of 30 years and will be of significant consequence in the long term. It has implications both for the presence of humans in the polluted areas and for the contamination of agricultural products that absorb radiation from the soil. The sale of products such as wild boar meat and mushrooms is currently prohibited. Even more restrictive conditions apply to rice, a staple food: depending on the direction from Fukushima, it may not be grown at all within 25 kilometres of Dai-ichi, and in some zones this ban extends to a distance of 60 kilometres. These figures apply to the current year; it is still uncertain what the situation will be in 2013. "The extent to which products accumulate caesium has not yet been investigated for all foods," says Christian Küppers, radiation protection expert at the Oeko-Institut. He thinks there may still be surprises in store and emphasises that extensive monitoring is still extremely important.

The radiological consequences are therefore enormous. They would be even more critical if the favourable wind conditions hadn't borne most of the radionuclides out over the Pacific. Despite this, the sea water in the immediate vicinity of the plant is now only lightly contaminated. This contrasts with the sediments on the sea floor. In early 2012 readings of over 1,000 becquerels of caesium isotopes per kilogram were still being obtained in the vicinity of the plant, and levels of several hundred becquerels were found at distances up to and exceeding 50 kilometres from Fukushima Dai-ichi. In sediment the contamination will remain at this high level for many years to come. Via marine creatures that feed there the contamination will enter food webs at concentrations many times these levels.

Over the past year some 88,000 people have had to leave their homes, at least for the time being. Present measurements indicate that some areas will no longer be safe for habitation even in the long term. Because of their geography and the prevailing winds they are more heavily polluted. If the standards that apply in Germany were enforced, these areas and some individual districts up to 60 kilometres away would not be lived in for a very long time.

Meanwhile the Japanese government is attempting to move people back into the polluted areas. Christian Küppers is not impressed: "Complete decontamination is not possible. Moreover, removing soil or washing down buildings does not render

Fukushima Dai-ichi: Two of the four devastated reactor blocks.

the radionuclides harmless. It would be better to abandon the heavily polluted areas for several decades, instead of exposing to risk people who have to clean up or who are expected to move back there."

Michael Sailer, CEO of the Oeko-Institut, is of the same view: "The authorities were initially too slow with the evacuation; now they are failing to provide clear information and are leaving people uncertain about their future." The internationally renowned nuclear energy expert visited Fukushima in January to see things for himself. "The technical extent of the disaster didn't surprise me," he said. But even more than Chernobyl, Fukushima brought home to him the social implications. "The effects of the radiation and the restrictions on land use as a result of the contamination are gradually unravelling the social and economic fabric of life."

"Fukushima is a living illustration of the challenges faced by radiation protection in an emergency of this sort," says Christian Küppers. He knows what he is talking about, having spent a quarter of a century studying the potential radiological consequences of reactor accidents. In 1999 the German government appointed him to its Commission on Radiological Protection; he is also a member of the nuclear emergency response unit set up by the government in 2009. "And we shouldn't forget that the radiological consequences would have been even more serious if the vast majority of the radionuclides hadn't been carried out over the Pacific," he warns.

Christoph Pistner goes on: "Even if accidents never recur in identical form, disasters involving large-scale release of radiation are possible in all reactors everywhere in the world. Not only Fukushima but also many other incidents and near-accidents in recent decades demonstrate that it is impossible to think of everything. We cannot really prepare ourselves – even highly developed industrialised nations like Japan cannot. We can of course attempt to make the complex core reactor system as robust as we possibly can. But that won't protect us from accidents of catastrophic scope in future. Neither better planning nor better disaster management can totally exclude accidents on this scale." *Katja Kukatz*

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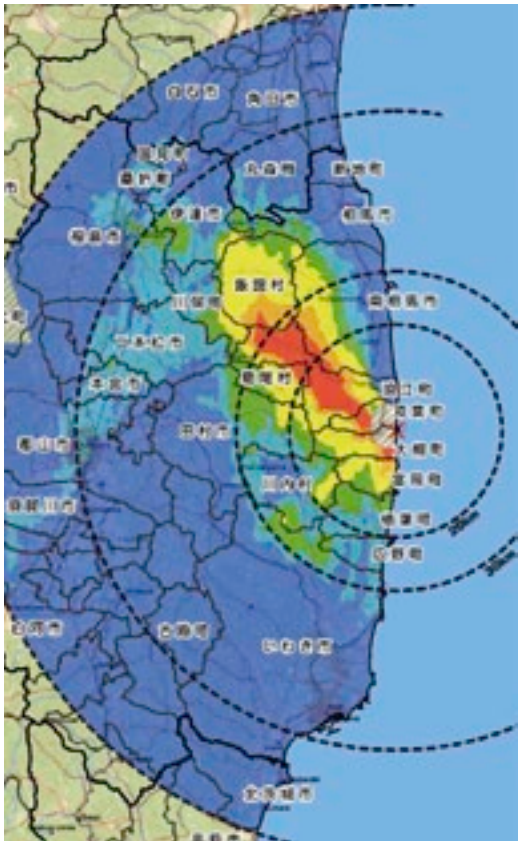
Local dose rates in the area around Fukushima Dai-ichi in June 2011



Local dose rate in microsieverts / hour

- 19 bis 91
- 9,5 bis 19
- 3,8 bis 9,5
- 1,9 bis 3,8
- 1,0 bis 1,9
- < 1,0

Under German radiation protection criteria people in the red and orange zones would be permanently resettled elsewhere. Even now people should still be moved out of these areas, because radiation levels will continue to represent a significant health risk for several decades to come. In addition, in the yellow, green and light blue zones the growing and marketing of agricultural products would be possible only on a very limited scale.

Source of diagram: Ministry of Education, Culture, Sports, Science and Technology, Japan

The accident unfolds

On 11 March 2011 a force nine earthquake shook the east coast of Japan. The quake caused a tsunami. Up to that moment three of the six reactor blocks at the Fukushima Dai-ichi plant were operational; the others had been shut down for maintenance. The fuel elements from Block 4 had been placed in storage pools. As is the plan in such cases, the plant and other nuclear power plants in the region shut down automatically as a result of the earthquake.

However, even after shutdown a great deal of heat is produced. This is normally removed by electrically operated cooling systems. However, the earthquake had destroyed large parts of the mains electricity grid. The plant was therefore dependent on an emergency power supply. But the tsunami flooded most of the site. This meant that the emergency power supply – and the backup cooling system – failed completely.

Without sufficient cooling the water in the reactor pressure vessels vaporised, until the fuel elements dried out and became greatly overheated. The vaporising water created high pressure. At the same time the steam reacted with the metal fuel rod casing, producing large quantities of hydrogen. This penetrated the reactor building, where it came into contact with oxygen.

There were then several hydrogen explosions in Blocks 1 to 4, causing varying degrees of damage to the reactor buildings. At the same time the fuel rods overheated to such an extent that core melt occurred in Blocks 1 to 3. The Japanese nuclear supervisory authority has given the accident at the Fukushima Dai-ichi nuclear power plant the highest rating on the International Atomic Energy Agency's INES scale: level 7.

Relic of the retired Rheinsberg nuclear power plant in the former East Germany. In addition to the automatic shut-down system, there is still an emergency shut-down button in every reactor today.

All change! Or carry on as before? The lessons the world is learning from Fukushima

What is the significance of Fukushima for the peaceful use of nuclear energy? Will nuclear schemes be quickly abandoned? Will there be rigorous safety reviews? Or will we see unswerving attachment to nuclear strategies? Germany has decided on a complete phase-out and the EU has agreed stress tests for nuclear reactors, but countries such as the USA have no intention of turning their backs on nuclear power. For all that, googling "Fukushima lessons learned" currently yields almost four million hits – including links to nuclear supervisory agencies as well as to universities, operating companies and other organisations such as the International Atomic Energy Agency IAEA. But very different lessons are being drawn from the disaster in different parts of the world.

Learning lessons from Fukushima does not always mean considering all possible risks. "Often the process simply involves reviewing the specific circumstances of the incident in detail – for example, the exact strength of the earthquake, the precise height of the tsunami and the reactor type. And then it is established that this particular sequence of events cannot occur at the site under consideration," says Gerhard Schmidt, expert in nuclear technology and facility safety at the Oeko-Institut. "By this method what people conclude from Fukushima is at best that an emergency diesel generator should no longer be placed in the basement of the machine house but on elevated ground nearby, or that there should be an independent system for filling

the fuel element storage pools with water. And with that the duty to evaluate important safety-related incidents is regarded as having been met."

When the vulnerability of German plants was reviewed in spring 2011, scientists refused to adopt this sort of tunnel vision or to focus purely on probabilities. Instead they also considered types of incidents that had previously been ruled out – such as extreme floods and earthquakes, the simultaneous failure of the external power supply and of all emergency diesel generators, and even a deliberate plane crash. "In view of the breadth of this spectrum, it is not surprising to learn that none of the plants would have reliably withstood all the projected events," says Gerhard Schmidt. Having realised that events as serious as those in Fukushima could also occur in German plants, the government decided to take older plants with lower safety margins out of service immediately, and to define a shorter remaining life for the newer ones in the Atomic Energy Act.

So far the IAEA's measures do not go nearly so far. The agency is often regarded as the guardian and enforcer of high international safety standards, although in the majority of member states its criteria are treated merely as recommendations. All the measures in its provisional Action Plan are ones that it approved of and reported in its bulletins even before Fukushima.

"The non-binding nature of the recommendations means that each country can carry on largely as it did before," is Gerhard Schmidt's criticism. "But privately diplomats definitely want to see independent supervisory authorities – something that should be a matter of course but is still ignored in a whole range of countries."

From Japan to Poland

After the accident the Japanese supervisory authority ordered extended checks before plants could be started up again. "But this also needs the approval of the responsible prefecture – which often has more restricted ideas than the central agency of the type and extent of the checks," explains Gerhard Schmidt. "At the moment it is completely unclear when which of the 54 Japanese reactors will be allowed to start up again." In March 2012 the majority – 52 of Japan's 54 plants – were still shut down.

European countries have responded to Fukushima in different ways. Belgium and Switzerland have decided not to build any new reactors and are limiting the lifespan of existing ones. In Italy, which has already phased out nuclear power, the proposal to build new reactors was defeated in a referendum. The future of nuclear energy in France will become clear after the presidential election of spring 2012: while the challenger is seeking to reduce the share of nuclear energy and favours a controlled shift to renewables, the current president wants to extend the life of all reactors to 60 years. A similar adherence to nuclear energy is also evident in other countries – at least in statements from official bodies. "However, the acquisition of nuclear energy capacity by Poland and Turkey is not yet certain to go ahead, since it still needs to be financed" says Gerhard Schmidt.

Despite the decommissioning of eight nuclear power plants, there is still a lot to be done on the nuclear issue in Germany – because nine plants will remain in operation for some years yet. The EU stress tests for Germany and the work of the Reactor Safety Commission (RSK) will yield further information on how well the plants would withstand extreme events. The supervisory authorities are also reviewing the extent to which current knowledge imposes additional requirements. "Even before the phase-out decision there were lists of retrofitting requirements. Of course, for the plants that remain in operation this is now a red-hot topic," says Gerhard Schmidt. And he adds: "At last thought is being given to actually carrying out this retrofitting." In his view there is also a need to clarify the applicable body of nuclear guidelines and standards. "For example, it is unclear how they need to be revised after Fukushima and when the updating that was begun some years ago will be applied on a compulsory basis in the plants," he says. "In particular, more modern elements such as safety management, aging management and the handling of the human factor must be incorporated into the applicable provisions."

In focus: The EU stress tests

It is also unclear what the effects of the EU stress tests will be. Around 140 European reactors must undergo the tests, the concept of which is based on a solvency check for banks under external strain. The reports drawn up by each country are due to be examined, evaluated and discussed by the other member states in a procedure that is already familiar from the international review meetings under the Safety Convention. But improvements are likely only if "backward" countries are exposed to public criticism.

In some ways the situation is paradoxical: for example, in most cases the plants have been confirmed to be safe, while at the same time retrofitting needs – sometimes on a large scale – have been identified. "It is now up to the supervisory authorities in the individual European countries," says Gerhard Schmidt. "They will determine whether the stress tests should lead to rigorous and far-reaching checks or whether the style of the IAEA, which is diplomatic and friendly but largely without consequences, will predominate. It remains to be seen whether major action will be taken as a result of the stress tests and whether this will mean the end for old, insufficiently designed plants."

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