The morning train from Slavutych is packed with commuters playing cards, browsing e-readers, or watching the monotonous flood plains pass by. It looks like any other routine journey to work. But rather than facing a crush through subway turnstiles at the end of the 40-minute trip, the workers are met by a row of full-body radiation monitors. It is the start of another day at the Chernobyl power plant, the site of the world’s worst civilian nuclear disaster.

As the train trundles through the bleak Ukrainian countryside, another nuclear crisis is unfolding halfway around the world. Barely a week after the partial meltdown at the Fukushima Daiichi nuclear power station, it is no surprise that some of the chatter on the train turns to the incident there. “It looks bad,” says one commuter. “But not as bad as Chernobyl,” he adds, with a hint of grim pride.

When Chernobyl’s reactor number 4 exploded in the early hours of 26 April 1986, the ensuing blaze spewed 6.7 tonnes of material from the core high into the atmosphere, spreading radioactive isotopes over more than 200,000 square kilometres of Europe (see ‘The hottest zone’). Dozens of emergency workers died within months from radiation exposure and thousands of children in the region later developed thyroid cancer. The region around the plant became so contaminated that officials cordoned off a 30-kilometre exclusion zone that straddled Ukraine’s border with Belarus. Today, a staff of about 3,500 enters the zone each day to monitor, clean and guard the site, where remediation work will continue for at least another 50 years (see ‘Half-life of a disaster’).

So far, the Fukushima accident is less severe. Radiation levels measured near the Japanese power plant have been less than those at Chernobyl after the blast there (see ‘Exposure in context’). And although radiation has spread from Fukushima, it does not match the amounts that rained down in the region around Chernobyl.

Despite those differences, the quarter-century of work following the Chernobyl disaster will offer some important lessons for Japan as the nation begins to assess the health and environmental consequences of Fukushima. The problems that followed Chernobyl also provide a grim reminder about the value of accurate information. Officials need to tell people immediately how to avoid the initial, most dangerous, exposure; yet in the longer term, scientists and the government must battle against unnecessary concern over low-level doses of radiation, which often causes more harm than the radiation itself.

In some ways, the connection between the two accidents may yield the biggest benefits for Chernobyl. For a brief window of time, the world has again focused attention on the largely overlooked work there. The renewed interest may spur nations to chip in the cash needed to complete the clean-up of the site, and to carry out health studies that have languished for want of proper coordination and funding. “In recent years, Chernobyl has been neglected by funding agencies and, to an extent, the scientific community,” says Jim Smith, a radioecologist at the University of Portsmouth, UK, who has studied the consequences of the accident for 20 years. “But not as bad as Chernobyl,” he adds, with a hint of grim pride.

After clearing a security checkpoint, the visiting researchers board a bus that heads...
towards the heart of the ageing power plant. They pass abandoned buildings and bump along potholed roads running beneath archways made of piping; since the accident, pipes have been laid above ground to avoid disturbing contaminated soil.

The visitors stop to look at the most visible reminder of the accident, the concrete sarcophagus that entombs the shattered reactor building. Completed hastily in November 1986, the sarcophagus was built to contain the escaping radiation, but it is now crumbling and streaked with rust. Smith whips a dosimeter out of his rucksack and poses for a photograph in front of the sarcophagus. The reading is 5 μSv h⁻¹; about 10 minutes of exposure at that level equals the same dose as an arm X-ray.

The plant's bright main office is a stark contrast to the sarcophagus. Stained-glass windows depict — in glorious socialist–realist style — the harnessing of atomic energy. But the plant has not produced power since 2000, when the last reactor was shut down. Valery Seyda, a deputy director of the Chernobyl Nuclear Power Plant, explains that the plant's top priority now is to construct a new confinement shelter for reactor 4 before the sarcophagus becomes too unstable. If it collapses before the new shell is in place, it could throw up a cloud of radioactive particles and expose the deadly remnants of the reactor.

**REPLACING THE RUSTING TOMB**

The plan is to build an enormous steel arch adjacent to the reactor and slide it along a runway to cover the building. The arch will reach 105 metres high, with a span of 257 metres — the world's largest mobile structure, according to its designers. It is expected to be in place by 2015 and should last for 100 years. It will enable robotic cranes inside to dismantle the sarcophagus and parts of the reactor. Longer-term plans call for finishing the clean-up work at Chernobyl by 2065.

Some of the concrete trenches for the project are in place. But the international Chernobyl Shelter Fund that supports the US$1.4-billion effort still lacks about half of that cash, and the completion date has slipped by almost ten years since the shelter plan was agreed in principle in 2001. One of the key goals of a forthcoming conference — Chernobyl, 25 Years On: Safety for the Future — to be held in Kiev on 20–22 April is to secure more cash commitments from international donors. Meanwhile, Chernobyl is developing long-term storage facilities for the debris that will be hauled out of reactor 4; and for more than 20,000 spent fuel canisters from the site’s other reactors, a facility that will cost about €300 million (US$420 million).

**HALF-LIFE OF A DISASTER**

1986 26 APRIL Owing to a flawed safety test, Chernobyl’s reactor 4 explodes, scattering debris from the core over a wide area.

27 APRIL A day after the blast, some 44,000 residents are evacuated from Pripyat, just 3 km from the reactor.

5 MAY The fire in the reactor is finally extinguished, having released 6.7 tonnes of radioactive material over 200,000 square kilometres.

6 MAY People and cattle are evacuated from a 30-kilometre exclusion zone around the plant.

AUGUST 4 months after the blast, 28 emergency workers have died from acute radiation sickness, caused by massive doses of radiation.

NOVEMBER Workers complete a concrete sarcophagus around the shattered reactor to limit further release of radiation.

1991 Cases of thyroid cancer in local children have risen ten-fold from previous levels.

2000 The last of Chernobyl's reactors is switched off.

2005 The United Nations Chernobyl Forum reports that no more than 4,000 people will die from the reactor’s fallout.

2011 25th anniversary conference expects to see lobbying for more funds for clean-up and health studies.

2015 New safe confinement shelter projected to be completed.

2020 Remediation efforts at plant’s cooling pond scheduled to be completed.

2065 Planned completion of clean-up at Chernobyl.
chief of the town's Communist party office, he was responsible for evacuating part of the town. Because he worked as a senior engineer at the nuclear plant, he knew that the disaster would have repercussions for decades to come. “I understood that I would never return to live in Pripyat,” he says, in an uncharacteristically soft voice. “I still feel some sense of loss.”

The evacuees from Pripyat also live with lingering fear about the radiation they were exposed to before fleeing their homes. Along with millions of others from the surrounding regions, they often attribute any sign of ill health to the accident. But pinning down Chernobyl’s true public-health impact has proved remarkably difficult.

There is little disagreement about the terrible fate of the workers who brought Chernobyl’s stricken reactor under control. Of 134 emergency workers diagnosed with acute radiation sickness, 28 died from their exposure within four months. Another 19 have died since from various causes, and many of the surviving workers now have cataracts and skin injuries.

More than 5,000 cases of thyroid cancer have so far been seen in people who were children at the time of the accident and lived in contaminated areas of the former Soviet Union — a more than ten-fold increase from normal levels (adults were mostly unaffected by the disease). Most of these cases were caused by drinking milk contaminated with radioiodine. Fewer than 20 of these people have died, but the sheer number of cancers, and their rapid onset within 5 years of the accident, surprised many epidemiologists.

This triggered a plethora of thyroid studies, most notably a long-term cohort study of 25,000 people in Ukraine and Belarus who were children in 1986 that is being coordinated by the US National Institutes of Health’s National Cancer Institute (NCI) in Bethesda, Maryland. The latest results from the Ukrainian section of this cohort1 confirm previous findings that the incidence of thyroid cancer is proportional to the size of the dose, with a particularly high risk seen in younger people and in those who were iodine-deficient due to poor diet. The research is having a direct impact in Japan, where those at risk of exposure are being given potassium iodide tablets to prevent the uptake of radiiodine in their thyroid.

The NCI oversees a second cohort made up of liquidators, a group of more than half a million people sent into the exclusion zone to help clean up and monitor the area after the initial emergency phase of the accident. Liquidators have a slightly raised risk of developing cataracts, and possibly a small increased risk of leukaemia2.

LONG-TERM EFFECTS

But what was the impact on the wider population? Various studies have tried to estimate how many deaths Chernobyl will eventually cause across the whole of Europe, but their answers range from a few thousand to hundreds of thousands3. Cancer causes about a quarter of all deaths in Europe, so teasing out Chernobyl’s far-reaching influence would probably be impossible, say epidemiologists. Moreover, focusing on such intangible factors would probably be impossible, say epidemiologists. Moreover, focusing on such intangible numbers can distract from the much broader social impact of the accident. In Ukraine and Belarus, hit hard by the break-up of the Soviet Union in 1991, lingering fears about radiation are thought to have contributed to a sense of hopelessness that is linked to high rates of alcoholism and smoking — factors that have a much bigger health impact.

“There’s tremendous uncertainty for these people,” says Elisabeth Cardis, a radiation epidemiologist at the Centre for Research in Environmental Epidemiology in Barcelona, Spain. “Some think they are doomed because of their radiation exposure.” Further research could provide convincing evidence that Chernobyl’s radiation did not significantly harm the wider population, but “we won’t know unless we look”, says Dillwyn Williams, a cancer researcher at the Strangways Research Laboratory in Cambridge, UK.

A handful of Chernobyl studies have found small increases in rates of breast cancer and cardiovascular disease, but they did not properly account for confounding factors, such as nutrition, alcohol consumption and smoking habits. And although some researchers have claimed to see an increase in genetic mutations in the children of parents irradiated after Chernobyl4, there has been no similar evidence of hereditary effects even in the children of Japanese atomic bomb survivors, who on average received much larger radiation doses.

This means that there is still a substantial gap in the overall understanding of Chernobyl’s health effects, says Williams. The problem is exacerbated by the piecemeal nature of previous studies. “There has been a failure of European-level coordination on this,” he says.

Williams hopes that there is now a chance to establish a Chernobyl Health Effects Research Foundation, which would mirror the highly effective Radiation Effects Research Foundation that monitors the long-term health impacts of the atomic bombs in Japan. Together, the efforts could reveal the differences between the single short-term dose of external radiation delivered by the atomic bombs, and the low-level long-term exposure seen after Chernobyl. Long-term doses were once thought to carry much less risk than the immediate exposure, but evidence is accumulating that the risks
Exposure in context

Many emergency workers at Chernobyl received lethal doses of radiation, but the broader public, even those living in the contaminated zone, were exposed to levels on a par with some medical procedures.

<table>
<thead>
<tr>
<th>Dose (mSv)</th>
<th>Source/implication</th>
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<tbody>
<tr>
<td>0.3</td>
<td>Total dose received by each resident of Europe for 20 years after Chernobyl</td>
</tr>
<tr>
<td>2.4</td>
<td>Average annual background radiation globally</td>
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<tr>
<td>3</td>
<td>One mammogram</td>
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<tr>
<td>120</td>
<td>Average total dose received by evacuees from Chernobyl plant and surrounding area</td>
</tr>
<tr>
<td>250</td>
<td>Upper annual limit allowed for Fukushima emergency workers</td>
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<tr>
<td>1,000</td>
<td>Causes temporary radiation sickness, including nausea and decreased white-blood-cell count</td>
</tr>
<tr>
<td>Up to 5,000</td>
<td>One minute’s exposure to Chernobyl core shortly after explosion</td>
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</tbody>
</table>

“Some think they are doomed because of their radiation exposure.”

Mark Peplow is Nature’s news editor.

5. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2 (NRC, 2006); available at http://go.nature.com/r7jea.