We Need to Talk About Nuclear Power

Facts, Fears and Fantasy

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Prologue
Rebellion

> 'The great enemy of the truth is very often not the lie, deliberate, contrived and dishonest, but the myth, persistent, persuasive and unrealistic.'
> – John F. Kennedy, US President, 1960–1963

He's not exactly in a good mood. It's odd, really. Here is one of the first and most authoritative scientists to warn about climate change, finding himself at the annual UN Climate Change Conference, where everyone is coming together to agree on lowering carbon emissions. This must be heaven!

Yet James Hansen is anything but thrilled. As we sit opposite each other, at the 2017 summit in Bonn, Germany, Hansen appears to have little faith. 'It's just words.'[1]

His signature hat is on the table between us. 'Politicians say we have to prevent catastrophic climate change,' Hansen continues. 'But a conference like this makes no difference. Government leaders pat each other on the back and smile politely for the camera. But all those words? Bullshit.'

It's safe to say the world's leading climate scientist is a little impatient.

He has every reason to be. Since the Kyoto Protocol in 1997, every climate treaty has had a negligible effect on greenhouse gas emissions. Despite all the promises, the concentration of carbon in the atmosphere has risen sharply. It seems we will have to learn to live with the consequences. According to Hansen, these consequences won't be mild.

The choice of Germany as host for the UN conference should be promising. Here, wind turbines and solar panels are making unprecedented inroads. Already, the German government has spent hundreds of billions of euros on these renewables.[2] The host country is considered a model country.

Hansen does not agree. 'Obviously, power from solar and wind is useful,' he explains, 'but cannot yet be stored long-term or affordably for when the weather doesn't cooperate.' In such cases, it's usually power plants using natural gas or coal that need to step in. Thus, moving away from fossil fuels by mainly using weather-dependent power is, in Hansen's opinion, 'not a good strategy'.

The figures prove him right. In recent years, carbon emissions from the German electricity supply have barely declined.[3] Indeed, in the year before the climate summit in Bonn, they went up.[4] Germany has some of Europe's most polluting coal-fired power plants.[5] The country's carbon emissions per capita are above the European average.[6]

And just who is James Hansen? The son of a farmer, he was born in 1941 in a small town in Iowa, in the corn-producing heart of the United States. While studying astronomy and physics, Jim developed an interest in the dust clouds surrounding Venus. He landed a job at NASA, the US space agency. There, his attention shifted.

The ozone layer in the atmosphere was being affected by chemicals used in everything from refrigerators and air conditioning to foam plastic and aerosols. All of this contributed to a greenhouse effect – an effect that, as Hansen learned, came mainly from burning fossil fuels. What impact would that have on his home planet?

He started tinkering with a programme on what was then the world's largest computer. During long days in the NASA lab in the heart of New York – just a few floors above Tom's Restaurant, renowned as the eatery in *Seinfeld* – he developed one of the first climate models. The scientist became alarmed.

Hansen started publishing papers and giving presentations. But it was only when he was invited to address the US Congress in 1988 that climate change entered the public's mind. His message: the Earth is getting warmer. Global warming already exists.

At that time, Hansen was head of the Goddard Institute for Space Studies, the NASA department dedicated to atmospheric change. He would remain so until he stepped down in 2013. By then, he had a hefty stack of studies to his name, held in high regard by peers.

As Hansen watched the evidence for global warming grow, he became frustrated with climate policy. Fossil fuels had been exposed as the biggest culprit. Yet coal, oil and natural gas provide some 80 per cent of global energy consumption – a share that has barely declined in the last 40 years.[7] Electricity from solar and wind may be on the rise, but in the global energy mix, their combined output sits at around 3 per cent.[8]

When politicians kept muddling along and he himself became a grandfather, Hansen realised: *We need to do more, and fast*.

Thus, the scientist became an activist. Hansen found himself handcuffed at protests against fossil fuels. He proclaimed that top executives at oil companies should be tried for high crimes against humanity and nature.[9] He compared coal transports to 'death trains' heading to concentration camps.[10]

And now, at the climate summit in Bonn, Hansen sees the future as bleak. 'We are facing an emergency,' he says. 'If we don't come up with a source of reliable zero-carbon energy soon, our children and grandchildren will have to. They will have even less time to repair the damage we cause.'

* * *

Thankfully, solutions exist. Just before our conversation, at a press conference, Hansen talked about one of those solutions – nuclear power.[11] From an objective point of view, this makes perfect sense. A nuclear power plant doesn't emit any greenhouse gases, and provides electricity 24/7.

In addition, as Hansen learned, there aren't that many success stories about weaning off fossil fuels and lowering carbon emissions. 'But the times when countries were able to produce a lot of new zero-carbon energy in a short time,' he says in Bonn, 'they did it with nuclear power.'

Apparently, that is an inconvenient truth to some. At the press conference, anti-nuclear activists, gathered together in one of the front rows, shook their heads ostentatiously. Once Hansen's presentation was over, they grabbed the microphone and started asking questions. Doesn't Mr Hansen know nuclear power has become incredibly expensive? Where does he want to store the waste for the next tens of thousands of years? Surely, in a modern democracy, nobody in their right mind would long for a revival of nuclear power?

Hansen is used to such resistance. Throughout society, nuclear power is met with deep-rooted suspicion. For many, nuclear has something evil about it, something sneaky. To them, there is a mysterious, ominous feel to it, a threat of imminent danger. It's almost as if the fission of atoms, as in a nuclear reactor, does not belong in this world.

Objections to nuclear power are well known. An accident could make large areas uninhabitable. The radiation released may cause diseases and deformities far and wide. At present, there's no way to safely store the waste for tens of thousands of years. The construction of a nuclear plant – averaging six and a half years between 2000 and 2021,[12] but running at well over a decade for new reactors in the United Kingdom, France and Finland – simply takes too long to mean anything in terms of reaching

climate goals. A terrorist gaining access to a nuclear plant could make nuclear weapons, or blow it up…

All these objections are easy to disprove, Hansen knows. But he also realises that not everyone is easily convinced. Now that he runs a small organisation and depends on donations, Hansen notices some of that rigid resistance. The vast majority of potential benefactors support his protests against oil pipeline construction and his calls for an international carbon tax, but when they hear that James Hansen, a hero to them and so many others, thinks nuclear power is actually a good idea, they flinch. *Nuclear power?!* It often leads to them not wanting to support his work.

Hansen shrugs. 'So be it.'

Like no other, Hansen knows the conversation about nuclear power is challenging. It's also a conversation that's inevitable. The role of nuclear power is not at all over. Around the world, some 440 nuclear reactors are in operation, spread across more than 30 countries, which together supply 10 per cent of all electricity.[13] In Europe, one in four light bulbs burns thanks to a nuclear plant.[14] On that continent, no other source produces more electricity.

It doesn't stop there. Some 90 reactors are currently on order or planned, and over 300 are proposed.[15] China alone announced in late 2021 that it wants to build as many as 150 nuclear reactors in 15 years.

The interest in nuclear power is not only because the climate is changing; the world is changing as well. Even before Vladimir Putin sent his army to invade Ukraine in February 2022, commentators pointed to the dangers of strong dependence on fossil fuels from Russia. With nuclear plants, which run on uranium that can come from anywhere, society has a constant source of zero-carbon energy.

Moreover, the demand for energy will increase significantly in the coming decades. If people in poor and emerging countries aspire to a better life, they will need a lot more energy. For their own well-being, it is better if that energy comes from power plants that do not pollute the air or disrupt the climate.

We never really needed nuclear power. Today it may be different.

Yet it is too early to say that nuclear power is on the rise. Between 1999 and 2020, a total of 104 nuclear reactors were started up. However, 103 have been shut down.[16] Nuclear power's share of the global electricity mix has plummeted from 17 to less than 10 per cent in the past 25 years.[17] A number of countries are determined to abandon it for good. Elsewhere, political support is fragile. An accident – not unthinkable, regardless of the chants of pro-nuclear advocates – could end construction plans just like that.

The Intergovernmental Panel on Climate Change (IPCC), the United Nations climate science body, indicates that the pace of nuclear power expansion is being 'constrained by social acceptability in many countries due to concerns over risks of accidents and radioactive waste management'.[18]

In Bonn, Hansen makes a comparison with Galileo Galilei, the astronomer who realised 400 years ago that the Earth moves around the sun. The authorities told Galilei that he

had better agree with their view of the Earth as the centre of the universe. Galilei swallowed. His silence made life a lot easier for him and he knew, Hansen tells us, that one day his findings would surface anyway.

'But today,' says Hansen, 'we cannot remain silent. If we sit back and say that in a few decades' time it will become clear that phasing out fossil fuels will not succeed without nuclear power, we will be right, but by then, it will be too late!'

James Hansen – the scientist, the activist – cannot help but tell it like it is. That's what he does when talking about the climate, and that's what he does when talking about nuclear power. 'The opposition to nuclear power is truly insane,' he sighs. 'All these fears – about radiation, about waste, about accidents – have no basis in science. This aversion is quasi-religious and irrational.'

Is it?

Is it, really?

4. Doomed
What went wrong in the world's biggest nuclear disaster?

> 'We're afraid of everything. We're afraid for our children, and for our grandchildren, who don't exist yet. They don't exist, and we're already afraid. People smile less, they sing less at holidays. (...) Everyone's depressed. It's a feeling of doom.'
> – Nadezhda Afanasyevna Burakova, resident of Khoyniki, Belarus, in: *Voices from Chernobyl* (1997), by Svetlana Alexievich

Things look bright for the residents of Pripyat. The town, built in the heart of nature near the old fishing village of Chernobyl, is a worker's paradise. Shops are well stocked. Thousands of young families eagerly await the festive opening of the amusement park.

Further along, a couple of tall, slim chimneys jump out, painted in red and white as if they were part of a candy factory. Over here, work is being done on the fifth and sixth reactors of the Vladimir Ilyich Lenin Nuclear Power Plant. It's a showpiece of Soviet might. When construction is complete, this will be home to the world's largest nuclear plant.

Viktor Bryukhanov observes with delight. Back in 1970, he arrived with his wife and a job: along the river in northern Ukraine he would build an *atomgrad*, an industrial town for the workers in the nuclear plant. From the start, this was the Party's prestige project and he, Bryukhanov, only 34 at the time, was to be a key shaper of the socialist dream of electrification!

What Bryukhanov lacks in nuclear experience, he makes up for with expertise gained in a coal fired power plant. Surely it can't be that much different? He goes to work. On top of an apartment building on the main square in Pripyat, he commissions a propaganda slogan: 'Let the atom be a worker, not a soldier!'

Now aged 50, Bryukhanov is more proud of his work than ever before. It's April 1986, and Labour Day celebrations are coming up. The rumours make merry. For outstanding performance, the staff is expected to receive a bonus on 1 May. Bryukhanov himself might be pinned with the Hero of Socialist Labour star, the highest state decoration, possibly followed by promotion to Moscow, the capital where, a year earlier, Mikhail Gorbachev took office as General Secretary of the Communist Party. Only a month ago, Gorbachev spoke at the Party Congress about the need for *glasnost*, openness. A new era was dawning. Gorbachev would break with bureaucratic secrecy.

Things turn out differently.

On the night of Friday 25 to Saturday 26 April, a safety test of reactor 4 fails spectacularly. The reactor explodes with a deafening noise. The three-metre-thick concrete roof is ripped open. The entire building shakes. Debris falls from the ceiling,

and the concrete walls buckle and bend. Pipelines jump. Lights go out. Some think: *the Americans have come*.

Chunks of hot uranium and graphite are scattered everywhere. Where a moment ago there was a reactor, now there is a boiling radioactive mush, open and exposed. The firefighters who have rushed in cannot put out the fires. Some become dizzy and vomit. They suffer from dry throats and severe headaches. In the next hours, ambulances race back and forth to the local hospital. There, some of the patients have swollen bright red faces.

Instantly, the doctor on duty recognises the symptoms: this is acute radiation sickness.

A day later, more than 200 patients are flown to a hospital in Moscow. They're mostly technicians from the power plant and firefighters, but also guards who had remained obediently at their posts, and construction workers who had been standing idly at the bus stop a bit further down the road, oblivious to the trail of radioactivity passing them by.

Information is missing. In Pripyat, it is decided, no one is allowed to leave town without permission. Telephone lines do not work. No sound is coming from the radios installed in the walls of all homes so that state propaganda can be heard in every living room. National television news does not report the events at the nuclear plant. Talk begins to circulate.

Only on Sunday afternoon is the silence broken, via local radio. 'Attention, dear comrades!'[1] There was an accident at the nuclear plant, and 'an unfavourable radiation situation is developing'. Thankfully, 'the necessary measures are being taken'. Unfortunately, in order to stay safe, residents need to 'temporarily evacuate'.

That same day, an endless parade of buses take nearly 50,000 people to surrounding villages. When a traffic controller goes to bed exhausted, she suffers a splitting headache and a sore throat. Her feet and ankles itch. As she arranged the evacuation, radioactive dust blew around her bare legs.[2]

Wind carries the dust particles along, further and further...

The next morning, in the early hours of a rainy day, the alarm sounds at a radiation monitoring point of a Swedish nuclear plant in Forsmark, north of Stockholm. A worker, on his way from the cafeteria to the changing room, notices that the warning device starts beeping at anyone who walks in. Could there be a leak in one of the reactors?

They find nothing.

Reports of radioactivity are trickling in from elsewhere in Sweden, Finland and Denmark. Air samples are taken. In the laboratory that day, these samples are found to contain particles of graphite, a crystalline form of carbon not present in Scandinavian nuclear plants. The wind is coming from the south-east. Had there been a nuclear plant accident in the Soviet Union?

Meanwhile, at a top-level meeting in Moscow, experts tell Gorbachev that the Chernobyl accident will be known soon enough in Europe. Might this perhaps be a fine opportunity to fulfil his recent promise of openness? Some nod, others frown.

Objections are raised. There may be panic, and nobody wants panic. Nobody wants to see a loss of prestige either. So when Sweden is on the phone that afternoon inquiring about a possible nuclear accident, the answer is that, no, *njet*, they know nothing about it.

However, in the evening, Radio Moscow confirms there was an accident. The information is sparse.

And all the while, agonisingly slowly, that invisible, mysterious cloud of radiation drifts across the European continent, through Mongolia towards Japan, and on to the US West Coast. Where rain falls, it is radioactive.

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What happened at Chernobyl was new to everyone, and the Soviets weren't exactly spilling too much information. In official messages from governments throughout Europe, a contradictory message shone through. People were ordered to throw away milk and spinach, and children had better not play in the sandpit, but the situation was under control. Really, nothing to worry about. Oh, but do throw away the milk and spinach, please.

Precisely because of all the secrecy, the accident at the now-closed Chernobyl became big news in the free West. Without a reliable source of information, journalists had to make do with speculation. Two thousand dead, one newspaper wrote.[3] No, 15,000, the same newspaper reported a few days later.[4] The bodies were said to have been dumped in mass graves.

Nobody was surprised. Everything in the Eastern Bloc appeared to be sinister. And hadn't it been said by many that a nuclear plant accident was only a matter of time? *This is what you get*, one could hear people thinking.

But: what exactly was 'this'? What on Earth was going on?

Whatever it was, this was not simply an engineering mistake in an industrial site, somewhere far away, at an unfortunate time. No, what had happened here, or so we began to think, was inherent in the technology of nuclear fission. This could easily happen again, anywhere. 'This' was a permanent source of harm, particularly to those nearby, but also across borders. And the worst part was the certainty that the damage would accumulate unnoticed in our bodies. An epidemic of cancer was inevitable, it was said. Tens, no, hundreds of thousands of people, no, as many as a million would die from the effects of the radiation released. And subsequent generations too, not just in the Soviet Union, but throughout Europe, even the world!

No one had experienced an accident like the one at Chernobyl before. There was so much uncertainty, but this we knew for sure: *this was by far the biggest industrial disaster ever*.

It cannot be overestimated how much influence information about the Chernobyl accident had on the perception of nuclear power among people who watched the news, in those years of the accident and its aftermath.

Over time, stories emerged about a wave of deformed children born in the wide vicinity of Chernobyl. One was Igor Pavlovets, a boy born in 1987 with one arm and underdeveloped legs. He was placed in an orphanage and told that his parents had died from radiation. After a British couple adopted him, Igor was the focus of a 1995 documentary on British television. There were many like him. A voice-over stated: 'The genetic legacy of Chernobyl is a million deformed children.'[5]

In Germany, a fairly little-known childrens' writer called Gudrun Pausewang had just finished a book (*Die letzten Kinder von Schewenborn*, or The Last Children of Schewenborn) depicting life after a nuclear attack. There was no happy ending. Convinced that nuclear energy posed an existential threat, Pausewang decided that any nuclear plant could experience something like what happened at Chernobyl. Reading the news, she wondered: 'What would a catastrophe like this look like in the middle of the Federal Republic? I have to warn against that.'[6]

In 1987, Pausewang published *Die Wolke* (translated as *Fall-Out*), a haunting read about a 14-year-old girl trying to escape the cloud of radiation after an accident at a nearby nuclear plant, becoming contaminated and losing her hair. There's no happy ending here either. The book became required reading in German schools, and shaped an entire generation's thinking on nuclear.

Pausewang's apocalyptic writings reflected an attempt to reckon with her own conscience. In her teenage years, she belonged to various Nazi youth organisations, believing Hitler's message until the war came to an end. In an essay looking back on why she wrote *Die Wolke*, Pausewang acknowledged, 'I don't want to be asked by my grandchildren and great-grandchildren, like the grandchildren and great-grandchildren asked their parents after the Nazi era: "And you? Why didn't you do anything about it?"'[7]

In 2019, a new generation became aware of what happened at Chernobyl. In *Chernobyl*, a miniseries by the leading US television network HBO, with a stellar cast, we saw actors falling down by the dozen. A heroic scientist, in search of the truth, explained that we should think of every atom of fissile uranium as a bullet, 'penetrating everything in its path', and the reactor explosion as an atomic bomb that goes off 'hour after hour' and 'will burn and spread its poison until the entire continent is dead'.[8]

While Soviet authorities were upgrading all nuclear reactors of the same, unique Soviet design to international safety standards, the accident triggered something else among government leaders in other countries. They lost confidence in their own nuclear plants.

From Denmark and Austria to the Philippines and New Zealand, governments closed perfectly functioning nuclear plants and scrapped construction plans for new ones. After Italy held a referendum on nuclear power in 1987, the government proceeded to close its plants. The Swedish Prime Minister was clearest when speaking about Chernobyl, saying, 'Nuclear power must be got rid of.'[9]

Around the destroyed reactor, radioactive debris was removed and a huge composite steel and concrete shelter was built. Meanwhile, other reactors at the plant were started up, providing power as usual. But the world had changed forever. Two years after the disaster, Moscow halted construction of three nuclear reactors elsewhere

in the country. Public pressure – a novel phenomenon since the Bolsheviks seized power in 1917 – could no longer be ignored. Thanks to a glimmer of *glasnost*, the people of the Soviet Union occasionally caught a glimpse of the aftermath in their newspapers. The death toll, they read, was a few dozen at most. But they didn't believe any of it.

Soon enough, the Soviet people came to realise that they had been deceived and misled, not only about what had happened at Chernobyl, but also about previous accidents at other nuclear plants and plutonium production sites for nuclear weapons that were now being cautiously discussed. Their country, it began to dawn on them, wasn't such a superpower after all. Despair and anger competed for primacy when they thought of the horrors under Stalin's rule; of nepotism in the Communist Party; of the senseless war in Afghanistan; of the everyday oppression to which they had become accustomed.

A good five years after the accident, it was not just the reactor at Chernobyl that had exploded. The entire Soviet Union had collapsed.

In 2006, Mikhail Gorbachev looked back on that episode. He viewed not his political reforms but the events at Chernobyl as 'perhaps the main cause' of his country's downfall.[10] The world's biggest nuclear disaster became the driver of the globe's biggest political upheaval in recent history.

Dwight Eisenhower got it right, albeit differently than he had imagined in 1953 when he told the United Nations about the peaceful uses of the atom. Nuclear power, previously deployed to end World War II, now helped end the Cold War.

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What exactly went wrong at Chernobyl? For a masterful reconstruction, British journalist Adam Higginbotham ploughed through reports for more than a decade and spoke to endless experts, former employees and local residents. His conclusion in *Midnight in Chernobyl*: this is what complacency can do in a failing state when combined with reckless disregard for nuclear power's real risks.

In their penchant for gigantomania, the Soviet nuclear specialists designed a reactor bigger and more powerful than any in the capitalist world. Their so-called RBMK reactors were cheap and easy to build. Also, you could – who would have guessed? – make plutonium for nuclear warheads. An ultra-thick concrete dome, preventing radioactive material from escaping the reactor building, was considered unnecessary.

'Nuclear power stations are like stars that shine all day long', it was proclaimed.[11] 'We shall sow them all over the land. They are perfectly safe!'

They were not.

Typical of the confidence was a ten-page article on nuclear power that appeared in *Soviet Life*, an English-language magazine intended to impress the outside world with all the splendour behind the Iron Curtain. Special attention was paid to Chernobyl. 'The plants have safe and reliable controls that are protected from any breakdown with three safety lines,' the Ukrainian Energy Minister said.[12] 'The odds of a meltdown are one in 10,000 years.' The article was published in the February 1986 edition.

Yet design flaws came to light from the outset. The RBMK reactor was unpredictable at shutdown. The emergency stop took as long as 18 seconds to have any effect. Inspections revealed flaws in the concrete. And whereas in Western designs the power output drops when the temperature rises in the reactor and the whole thing thus slows down, Soviet blueprints had it the other way round.

Problems were brushed aside. In fact, any criticism could mean dismissal. After all, hadn't the authorities said nuclear plants were perfectly safe?

Accidents did occur. In 1975, the first RBMK reactor, in Leningrad, had been in operation for less than a year when a concrete tank with radioactive gases exploded. A month later, the cooling circuit broke down, leaking radioactive water and killing three workers. Another few months later, radiation was released after damage to the fuel channel where water is converted to vapour.

Whenever an accident was investigated, it was always said to be due to a manufacturing error or staff inattention, never the design of the atomic scientists. If the information was shared at all, it was not with people working in the nuclear plant, and certainly not with local residents.

In the centrally planned economy, things went straight from the drawing board to the construction site. Completion dates for engineering projects were unrealistic, so everyone fiddled and skirted the rules. The roof of the turbine hall at Chernobyl was clad in highly flammable bitumen, but a fire-retardant alternative was not available in the Soviet Union, so it was tolerated with a blind eye. Because there could be no unemployment in the workers' paradise, busloads of men and women arrived at the construction site with no idea of what to do. Engineers and electricians had no particular knowledge of nuclear plants.

Before starting operation, the fourth reactor at the Chernobyl nuclear plant – the most modern, most advanced – had to undergo a key safety test. This was a time-consuming job. To finish on time in December 1983, as planned, the test was postponed.

The following year, the test was suspended again.

And then again.

Meanwhile, in the control room, engineers were having great difficulty cranking up and shutting down the reactor. The valves and flow meters proved unreliable. Adjustments were made by intuition. The control panel, with hundreds of switches, buttons, dials, meters and lights, soon showed wear and tear.

When at last the safety test of reactor 4, designed to see if the system could withstand an electrical blackout, was scheduled for 25 April 1986, permission had not been requested. That day, the test was cancelled after all, because the reactor would have had to shut down, while factories in the area needed every kilowatt to meet their production quotas before Labour Day. The testing would have to be done at night.

The night shift, however, was not prepared for the test. Upon entering, Leonid Toptunov, senior reactor control engineer, saw for the first time a stack of papers with

instructions for the test. He had only two months' experience in operating the reactor. He was 25 years old.

During the test, when reducing power, the reactivity meter unexpectedly dropped further than intended, almost to zero. This was certainly not planned, but no recipe for disaster. They should have called off the test, and simply shut down the reactor. They should have left things as they were for a day, and then they could start it up again.

But the test had to continue.

At least, that's according to Anatoly Dyatlov, deputy chief engineer of the nuclear plant and in charge of reactor 4. Here's how Higginbotham describes Dyatlov:

> 'He was rarely in his office but prowled the corridors and gangways of the plant day and night, inspecting the equipment, checking for leaks and errant vibrations, and keeping tabs of his staff. (...) He had no tolerance for shirkers or those who didn't follow his orders to the letter. (...) He could be high-handed and peremptory, peppering his speech with curses (...), muttering to himself about the inexperienced technicians he dismissed as *chertov karas* – fucking goldfish. He demanded that any fault he discovered be fixed immediately and carried a notebook in which he recorded the names of those who failed to meet his standards.'[13]

Much to his chagrin, Dyatlov had been waiting all day to supervise a test which kept getting pushed back. Enough already! Dyatlov ordered the power to be increased. *Pull up those damned control rods!*

Toptunov protested. Doing so would make the reactor go out of control. This couldn't be right, could it?

Dyatlov, worn out after a long working day, started threatening. Did he have to go and get someone else to do the job?!

Toptunov realised that disobedience would mean the end of his budding career. By obeying, however, his career would still end, and more than just that. When he withdrew the control rods, disaster was inevitable…

After the explosion, things continued to go wrong. According to the dosimeters, radiation levels didn't seem too bad. In reality, those instruments could only measure low levels of radiation. The dials went out completely, and these measurements were then obediently passed on. Nobody dared to question the equipment or worry their superiors.

Some did not even want to acknowledge that the reactor had been destroyed, leaving men risking their lives for a futile attempt to regulate cooling water. Gorbachev learned over the phone that the reactor – the one that was completely in ruins – would soon be restarted. Director Bryukhanov sat idly by.

In the next days, during endless meetings, senseless decisions were made, just to keep up the illusion that the situation was under control. However, no one told residents

in Pripyat to close windows and stay indoors. No one advised them to avoid local milk. Even the hundreds of thousands of men who were summoned to clean up the area for a considerable length of time were poorly protected from radiation. Often they did not even wear masks or gloves. Dust got into their eyes and mouths, and stuck under the clothes they kept on at night.

Mikhail Gorbachev, the darling of the West who was praised for his communication skills, remained silent. *Glasnost*, but not yet. Only after 18 days did he break the silence. In a televised speech, Gorbachev complained of 'a veritable pile of lies, the most unscrupulous and spiteful', all designed to 'denigrate' the Soviet Union.[14]

The government commission's official investigation stated that nothing was wrong with the reactor, that the staff had made mistakes and that supervision was inadequate. Viktor Bryukhanov and Anatoli Djatlov became scapegoats.[15] They had ignored protocol and were sent to a penal colony for ten years. The former endured his humiliations resignedly, the latter bitterly.

While they were imprisoned, more investigations into the accident followed. The International Atomic Energy Agency (IAEA) ruled that the design was flawed. One author of a report by the state's independent nuclear safety board put the cause of the disaster as a combination of 'scientific, technological, socioeconomic and human factors' that occurred exclusively in the Soviet Union.[16]

Leonid Toptunov, who operated the reactor, was posthumously awarded the Ukrainian Order for Courage. On his deathbed, he said in a weakened voice: 'Mama, I did everything right. I did everything according to the regulations.'[17]

* * *

How many lives did the accident at Chernobyl take?

The attendant at the circulation pump was killed instantly, vaporised on the spot by the heat, or perhaps crushed by the debris. A few hours later, a colleague who had been trapped in the havoc and could barely move his lips died of burns in hospital. Soviet authorities kept this total of two as the official death toll for a long time.

But it did not stop there. We turn to the scientific literature. In 2006, an updated version of *Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts* was published, written by the Chernobyl Forum, a collection of eight UN agencies, including UNSCEAR, the United Nations Scientific Committee on Atomic Radiation, the World Health Organisation (WHO), the UN Environmental Programme (UNEP) and the World Bank, supplemented by the governments of Ukraine, Russia and Belarus, with the participation of about a hundred acknowledged experts. This is the most authoritative source on Chernobyl. What does the report say?

It turns out another person died of a heart attack at the scene.[18] That makes three.

Some 600 workers and firefighters needed first aid after the explosion. In 134 of these cases, we read, doctors diagnosed acute radiation sickness: a collection of symptoms that emerge after exposure to a high dose of radiation over a short period of

time. They were tired and nauseous, vomited and had diarrhoea. For a while they seemed to recover, but then things got ugly, in keeping with the syndrome. Their lips became covered with thick, black blisters. Their gums turned red. They developed painful sores. Their hair fell out. Their skin turned red and purple, then brown-black before peeling off. Infections developed. The walls of their intestines were eaten away, ultimately coming out as bloody diarrhoea.

After months of gruelling treatment, most were on the mend, although cataracts and ulcers remained common. However, before the end of the summer, 28 patients would succumb to radiation and burns.

We are at 31 fatalities.

By 2004, out of that group of 134 people with acute radiation sickness, 19 had died, from a variety of causes. Potentially linked to radiation were five cases of cancer, but certainly not those who died from heart attacks, tuberculosis or car accidents. We regret the fate of these 19 unfortunate people, but, following the lead of the UN expert group, we leave them out of our tally of Chernobyl deaths. We're still at 31.

Cancer sets in later. Thyroid cancer is a well-known result when radioactive iodine accumulates in the thyroid gland, especially in children. The iodine can get there if one drinks milk from cows that grazed on pastures contaminated with radioactive fallout. And indeed, in the first few years after the Chernobyl accident, researchers noted an increase in thyroid cancer. By 2002, some 4,000 cases of the disease had been detected in people who were under the age of 18 at the time of the disaster and were among the more than 8 million people living in the worst-affected areas in Ukraine, Belarus and Russia. Fortunately, thyroid cancer is highly treatable, and once it's been diagnosed, patients can usually be completely cured. Death from thyroid cancer occurs in exceptional cases, mostly when the disease goes undetected or is detected too late. Chernobyl Forum researchers put it at 15 deaths in this group.

We are at 46 deaths.

But hey, it's only 2006, the authors realise. Fate can still strike at any time. Some cancers do not appear until later. A precise calculation is complicated, because here we have to rely on complex mathematical models full of assumptions and uncertainties about what radiation does in the body. Long story short: among over 5 million rescue workers and local residents in 'contaminated' – the report has the word in inverted commas – areas, we could expect around 4,000 additional cancer deaths in decades to come, mostly amongst those who worked as liquidators.[19]

There is more literature. One study is *Health Effects due to Radiation from the Chernobyl Accident*, published in 2011 by UNSCEAR. The findings hardly differ. No convincing increase in breast cancer. No measurable effect on fertility. No evidence of an increase in birth defects.

And that's it. In a population of many millions, no more than a few dozen identifiable deaths, plus up to the year 2065, several thousand premature deaths from a disease that, for a variety of reasons, frequently occurs in old age and can, indeed, theoretically be linked to radiation.

By comparison, in 1984, far away in Bhopal, India, a gas leak at a Union Carbide insecticide plant instantly killed some 4,000 people.

Countless heartbreaking stories, such as the one about the disabled Igor Pavlovets with his one arm and underdeveloped legs, were investigated. They were sometimes fabricated, other times heavily contrived, but not one had a demonstrable or plausible link to radiation. Physical and mental abnormalities were common before Chernobyl; they were not more common after. The increase in reports of birth defects in Belarus is attributed to better reporting and kept pace with an increase in other, non-contaminated areas.

Rumours are persistent. One is about the so-called Bridge of Death. Here, residents of Pripyat had stood watching the fire at the nuclear plant, three kilometres away. They are said to have all died. In *Chernobyl*, HBO's miniseries that the makers say is based heavily on a collection of personal anecdotes collected by Svetlana Alexievich,[20] a young dad is standing behind a buggy, watching from the railway bridge. Children look in amazement at the snow swirling from the sky. In a later scene, we see the father with his baby in hospital, begging for help. Both have burns on their skin.

The credits at the end of *Chernobyl* state: 'Of the people who watched from the railway bridge, it has been reported that none survived.' That wording is correct. 'It has been reported', indeed, that all those spectators died. But that doesn't make it true. In reality, they carried on with their lives. The story of the Bridge of Death is an urban legend.

There are many such tales. Another common one is of a helicopter that crashed while the pilot was trying to dump a load of sand or boron to put out the fire in the reactor. And indeed, in *Chernobyl* we see a helicopter crashing, seemingly swallowed by the extreme radiation above the smouldering reactor. In reality, a helicopter crashed only months later, when the fire was long gone, after one of the rotor blades collided with a chain dangling from a construction crane.[21]

'They seem like small things,' Adam Higginbotham, the author of *Midnight in Chernobyl*, said in an interview, 'but there's this accretion of all these small things that are constantly repeated, that creates this mythological version of the Chernobyl accident.'[22]

According to Higginbotham, the fabrications meet our worst expectations of what a nuclear accident brings about. They're stories that are, he says, 'conveniently horrifying'.

In other words, such stories go in easily. They just don't go out again so easily.

* * *

A pressing question arises. How is it possible that Chernobyl did not claim more lives?

Is it perhaps impossible to link health problems, illnesses and causes of death directly to radiation? After all, one cannot tell from a cancer cell just why and how it was

formed. Even complaints of the heart or the liver can have all sorts of causes. Can some of these deaths be traced to Chernobyl?

Not likely, experts say. In the years since, there has been no marked increase in any disease in the wider area that can be traced to Chernobyl with any justification. Still, it doesn't stop people from attributing a range of ailments to radiation, even tuberculosis or hepatitis, even though these are infectious diseases caused by viruses.

Nevertheless, while plenty of anecdotes may not add up to scientific evidence, they do seem to indicate *something*. Anatoly Grishchenko, one of the helicopter pilots who spent days dumping sand over the reactor, died of leukaemia in 1990. Was his death caused by the disaster? Well, that is difficult to determine. According to all the best available knowledge – based on the long-running study of survivors of the atomic bombs on Hiroshima and Nagasaki – leukaemia typically occurs between 10 and 15 years after exposure; before and after that, the likelihood of leukaemia is dramatically lower. Perhaps, who knows, it formed in Grishchenko's case much faster than usual? Maybe he is indeed among the few thousand extra cancer cases. Maybe not.

What about Alexander Yuvchenko? He was a mechanical engineer in Chernobyl who received blood transfusions and skin transplants in hospital. After a year, he was allowed to go home. He died in 2008. Was his leukaemia due to the disaster? It could have been, but again it is tricky, as we are now more than 20 years on. Leukaemia could just as easily be caused by something else: hereditary predisposition, exposure to chemicals, treatment with certain drugs. We will never know the cause of Yuvchenko's leukaemia.

So doubt remains.

Another possible answer. Could it be that doctors were reluctant to attribute their patients' symptoms to the accident? Yes, that was a factor. A diktat from Moscow stipulated that the word 'radioactivity' was forbidden if patients were not overtly suffering from radiation sickness and burns. A new diagnosis became popular: vegetative-vascular dystonia, an amalgam of a whole range of vague symptoms, such as palpitations, headaches, depression, fatigue, irritability, nausea, dizziness, sweating, wheezing, coughing and frequent urination. The diktat suggests that health damage has been deliberately glossed over, but according to the best knowledge, these psychosomatic complaints cannot be due to radiation.

Might it be difficult to uncover reliable information from a country that had become used to falsifying or obfuscating documents? It is hard, indeed, except that there were troops of international investigators on the ground to find out the truth. They were put to work with millions of euros of research money from Western governments and European institutions. If anything, it would be tempting for the researchers to report on an increase in all kinds of diseases, because it would add importance to their work, and more research money and commissions would come their way.

But no matter how they searched, they found nothing.

Wait. Perhaps there was a big cover-up? Has the nuclear industry been trying to whitewash the truth?

It wouldn't be the first time. In 1982, there was a partial meltdown at Chernobyl. Following maintenance, a cooling valve remained stuck. Once the reactor was turned back on, a tank overheated and ruptured. The accident was only noticed hours later when radioactive particles had already escaped through the ventilation system, carried along by the wind and precipitated by rain. A clean-up operation was required, but the accident was not made public.

A cover-up is not such a crazy idea. No doubt the owners of the Three Mile Island plant in Harrisburg, Pennsylvania, would have liked to cover up their accident back in 1979, just as they did in the film *The China Syndrome* [see Chapter 3]. Such a course of action is not alien to any line of business and seemed ingrained in the nuclear industry, with its tendency towards secrecy and mendacity.

Two accidents in the autumn of 1957, at a time when everyone was still enchanted with nuclear power, demonstrated this. First, an underground tank full of plutonium waste exploded at a secret military site deep in the Urals. Soldiers, bleeding and vomiting, were taken to a hospital. A drizzle of thick, black snow fell on surrounding villages. Soviet authorities were silent about it. Some 10,000 local residents had to guess why they were evacuated. No information was provided. How could something have happened in a place that officially did not exist?

Less than two weeks later, a fire broke out at the newly opened nuclear plant near Windscale along Cumbria's coast. While the fire persisted, a typical newspaper article such as the one in *Shields Daily News* reported on page 12 that the state authorities were reassuringly saying that 'continuing measurements outside the site confirm there is no evidence of any increase in radioactivity which might have caused harm to the public'.[23] Here, we see the British government lied at first, saying the released radiation was completely harmless. Then it started to turn: farmers far and wide had to throw away their milk for months to come. Finally, it withheld the truth: the Prime Minister had the investigation report confiscated before publication.

Covering it up – that seems to be the obvious response for any nuclear accident, anywhere. Was the truth about Chernobyl covered up?

Yes, believes Kate Brown, a professor of science, technology and society at the Massachusetts Institute of Technology. In her 2019 book *Manual for Survival*, she states that there were at least hundreds of thousands of deaths: a claim that had long been buzzing around in certain circles. Soviet researchers, writes Brown, would have been forbidden to report on the 'stunning increases' in cancers, birth defects, child mortality and many other conditions.[24]

Brown candidly distrusts solid scientific studies. A strong proponent of oral history, she prefers to dwell on encounters with distraught doctors, outraged activists and people who believe they are suffering from all sorts of ailments due to the accident in Chernobyl.

Time and again, Brown suggests that the United Nations has done everything in its power to suppress the truth about the scale of the disaster. The UN is determined to withhold the facts, Brown argues, because its main member states possess nuclear weapons, and if the truth about hundreds of thousands of Chernobyl radiation deaths

were accepted, these countries would also have to acknowledge that radioactive fallout from atomic testing has caused widespread damage. These atomic tests, she writes, were the 'most suicidal era in human history',[25] meaning they must have led to more than the tens of millions of deaths during World War II.

Evidence of so many deaths or of attempts to suppress the truth remains lacking, or it must be that UN researchers ignored studies of questionable quality. 'Somewhat selective,' is her assessment of their work in an interview with pro-nuclear activist Michael Shellenberger.[26] 'They tossed out this work they didn't like.'

On publication of her book, Brown wrote an opinion piece for *The Guardian*. The headline: 'Chernobyl's disastrous cover-up is a warning for the next nuclear age'.[27]

With her continuous insinuations, Kate Brown builds on a debating style that has become popular among opponents of nuclear power. A famous exponent is Helen Caldicott, the Australian physician who rose to fame in the 1970s with her passionate fight against nuclear weapons before gradually turning her sights on nuclear plants [see Chapter 3]. Caldicott called the studies on Chernobyl 'a total cover-up' and 'the biggest medical conspiracy in the history of medicine'.[28]

There are parallels with other public debaters who use bold, even outrageous allegations and imputations to cast doubt on scientific conclusions. For example, we sometimes hear claims that vaccines are unsafe and that the pharmaceutical lobby dictates the outcomes of studies. Those who say such things rarely play a significant role in public debate.

And that's the crazy thing: whereas deniers of vaccine safety are met with widespread disapproval and seen as conspiracy theorists, unfounded exaggerations of the consequences of Chernobyl are remarkably often endorsed. Kate Brown's book received rave reviews in *Science* ('a must-read')[29] and *Nature* ('a page-turner'),[30] and was praised in *The Economist* as 'a magisterial blend of historical research, investigative journalism and poetic reportage'.[31]

The British TV documentary about young Igor Pavlovets, symbolising 'a million deformed children', won an award at the Prix Europa, the biggest awards festival for European media producers.

Die Wolke became a bestseller and was awarded several literary prizes, while author Gudrun Pausewang received the German Youth Literature Award for her life's work and was awarded the Order of Merit of the Federal Republic of Germany.

Chernobyl went on to become the series with the highest audience ratings ever and was showered with Emmy Awards and Golden Globe Awards.

Svetlana Alexievich, the journalist who compiled the collection of anecdotes on which the makers of *Chernobyl* relied, was awarded the Nobel Prize in Literature 'for her polyphonic writings, a monument to suffering and courage in our time'.[32]

The observation that the radiation released after the world's biggest nuclear disaster actually caused very little death and destruction raises uncomfortable questions. When looking for answers, some develop an unwavering suspicion that hundreds of experts associated with various United Nations agencies and national governments, plus a

whole series of doctors, researchers and government officials from different countries spent decades successfully concealing the cause of death of hundreds of thousands or even many millions of people.

Others raise an entirely different question, which may sound equally crazy when writing it down: could it be that radiation is not nearly as terrible as we think?

5. A strange glow
How dangerous is radioactive radiation?

> ‘Radioactivity
> Is in the air
> For you and me.’
> – Kraftwerk, German pop band, in: ‘Radioactivity’ (1975)

If you’re reading this book at home, radiation is hitting you from the masonry in the walls. If you’re outside on a bench, radiation is coming from the cosmos as well as the earth. When gardening and digging in the ground, or when going on holiday in the Alps, you increase your exposure to radiation. If you go by plane, you receive even more. Even if you stay in the UK and drive an hour from, say, Swindon to Bristol, or from Central to East London, the radiation level will double.[1] Want to avoid it completely? Good luck. You will have to drive a little further and leave this universe.

Much of this so-called ionising radiation – in popular parlance: radioactive radiation – can be traced back to the Big Bang. Radiation is therefore not some unnatural phenomenon we modern humans have introduced into our living environment. On the contrary, it has made us who we are.

Some of that radiation gets into our bodies. At the end of each day, we have consumed a few more radioactive substances, for example, when we eat meat or fish, or add garlic to a pasta sauce.

In other words, we ourselves are radioactive.

A portion of the radiation we bathe in every day is not natural. It’s in the atmosphere due to the fallout from atomic tests and the meltdowns of nuclear reactors, even now, after decades.[2] A much larger piece of that artificial radiation – and this is a part that is steadily increasing – reaches us only with our consent, such as when we submit to diagnostics or treatment in hospital.[3]

Yet there is something eerie about radiation, whether it comes from a nuclear reactor, the cosmos, garlic or a CT scan. Just the word ‘radiation’ makes us feel uncomfortable. We cannot see it, hear it, feel it or smell it. This leads to mythology. Radiation can spread all over the world without our senses noticing any of it. *How can we ever be safe?*

Radiation is a special force of nature. It can make us sick, or cure us. It can kill us, or save our lives.

The ambiguity of radiation also struck the introverted professor of physics at the University of Würzburg who stumbled upon it. On a Friday afternoon in November

1895, Wilhelm Conrad Röntgen conducts an experiment in the laboratory below his living room using, among other things, a tube, a piece of cardboard, a filament, a metal plate and electric current. That day, however, the light he thus creates under atmospheric pressure – as many of his contemporaries did – illuminates more than just the tube. A faint yellow-green glint appears on a screen of barium salt that happens to be nearby. Yet the tube is wrapped entirely in black cardboard. How can that be?

Throughout the weekend, the professor continues to experiment. A mirror does not deflect the invisible rays. They pass right through cardboard, a thick book, a metal plate and a piece of wood. Only lead can stop them. Holding his hand between the tube and the screen, Röntgen sees a blurred outline of his bones. The image horrifies him.

No law of physics can explain the mysterious behaviour of these powerful rays. When writing an article about his findings, Röntgen doesn't quite know what they are or what to call them. He refers to them as 'X-rays'. Against his wishes, others start calling them after him: 'Röntgen rays'.

For a long time previously, it didn't look like Röntgen would make one of the most important scientific discoveries of his time and receive the very first Nobel Prize in Physics. At school, Wilhelm was not a high-flyer. The son of a Dutch mother and a German textile merchant, he studied at the Technical School in Utrecht, where his performance in physics was assessed as very poor. After being expelled from school, as punishment for an unflattering cartoon of a teacher, he was refused admission to the university; his command of classical languages was insufficient.

Röntgen moved to Switzerland, obtained his doctorate and met the woman he later married. His wife, Anna Bertha, would appear in all subsequent stories about Wilhelm Röntgen, as she lent her left hand for a photographic print of X-rays. When she saw the photograph of her bones, with the wedding ring clearly visible, she became upset. According to legend, she exclaimed: 'I have seen my death!'

Röntgen's discovery doesn't go unnoticed. Articles appear in newspapers everywhere. Doctors in particular realise its practical usefulness. Now they can look inside their patients' bodies without cutting into them. Within weeks, Röntgen receives a royal award. Within two months, there's the first medical application. A man in Canada has been shot with a revolver on Christmas Eve, somewhere in his leg. But: where's the bullet?

According to the prevailing custom of the time, doctors would wriggle their fingers into the wound, but they couldn't always find what they were looking for. This method was not without danger, as disinfection was not yet in vogue; only 15 years earlier, then-President of the United States, James Garfield, lost his life after a doctor used his unwashed fingers to look for a bullet between muscles and tendons, causing a deadly infection.

But now everything is different. Now we have X-rays!

The leg of the stricken Canadian man is photographed, revealing the inside. The photo is slightly underexposed, but the bullet is detected and removed. The man who took the picture, John Cox, would in the following years work with the young Ernest Rutherford [see Chapter 1] and nominate him for a Nobel Prize.

Yet the principles behind the X-rays were still anyone's guess. The answer came unexpectedly from a woman – the first to establish herself in modern science, and become the most famous woman in the world.

* * *

Growing up in Warsaw, Poland, Maria Salomea Skłodowska, like all girls, is forbidden to study. Her country is under the thumb of the Russian empire that has annexed Poland. The natives are not even allowed to speak their own language. Maria's father, a widower since losing his wife to tuberculosis, allows her to study secretly in the evenings, after working as a nanny for affluent families during the day. In 1891, she is admitted to the University of Paris.

Paris! The brand new Eiffel Tower rises above everything. Underground, the metro is coming. Streets and fountains are electrically lit. As the modern world takes shape, Marie, as she is now called, lives on bread with butter and tea. Her room has no heating; in winter, she sleeps with all her clothes on and in a thick coat.

After graduating in physics, Marie goes to work in a grubby laboratory she shares with Pierre Curie, a slightly older physicist who builds his own measuring equipment and still lives with his parents. In 1895, a year after their acquaintance, they marry. Their honeymoon is a bicycle ride.

A little later, when Marie Curie is looking for a topic for her dissertation, she learns of Wilhelm Röntgen's X-rays. Everyone is talking about them. One of her lecturers, Henri Becquerel, had tested his entire collection of fluorescent minerals – a hobby – and discovered that uranium emits X-rays. Becquerel speaks of 'rayons uraniques'. Curie will change it to 'radioactivity' when she examines all kinds of minerals, metals, salts and oxides in the laboratory and finds that thorium produces the same rays. X-rays are not reserved for uranium.

Perhaps, she suspects, radioactivity is a property of atoms?

More research is needed. The university offers her an abandoned wooden shed with a leaking roof where corpses were cut open for autopsy not long before. Here the Curies have a shipment of uranium ore delivered from the Bohemian town of Joachimsthal, where uranium was abundant in the silver mines [see Chapter 2]. The stuff had been dumped in a pine forest. The owner had it brought over by horse-drawn cart for just expenses. The bags are still full of pine needles.

Then the hard work begins. Marie pours litres and litres of liquid into a cast-iron pot, sometimes stirring the boiling goo for hours with a huge iron rod. In this way, she purifies two radioactive elements in 1898. One she calls polonium, after her native country; the other radium, derived from the Latin radius, for ray.

Out of love for science, the Curies do not patent anything. They are proud of their work. Pierre puts bowls of radium in the courtyard near the lab; the extraordinary blue glow impresses visitors. Marie often carries a vial of radium in the breast pocket of her lab coat, just to take a look at it.

Their work caused a shockwave, just like the earlier discovery of X-rays. Radiation, we now know, is not a result of interaction between one element and another. It's the result of the constant and gradual release of unprecedented amounts of energy stored in atomic nuclei in the interior of certain elements.

How can that be? The Curies do not know when in 1903 they share a Nobel Prize with Henri Becquerel for their discovery of radioactivity. The explanation for the peculiar phenomenon comes two years later thanks to a 26-year-old man who neither teaches at a university nor researches in a laboratory, but works as an assistant in a patent office in Bern, Switzerland, in the Electromagnetic Apparatus Department. His name: Albert Einstein.

In 1905, Einstein publishes no less than four seminal papers that turn physics on its head. In one, he lays the foundations for the most famous equation ever, penned in the *Jahrbuch der Radioaktivität und Elektronik*: $E=mc^2$.[4] It offers an explanation for the immense energy that can be released when an atom is cracked open, as later seen in nuclear fission. The energy (E) coming from atoms as radiation is the mass (m) it has lost, multiplied by the square of the c of celeritas, the speed of light.

The worldview shifted. Reality, Einstein taught, consists not so much of matter as of time and space.

We can all take comfort in knowing that even Einstein himself struggled to understand what all this meant.

* * *

In the case of Hans Castorp, the main character in Thomas Mann's 1924 masterpiece *The Magic Mountain*, his experience of radiation began when he had an X-ray of his chest taken at a sanatorium:

> 'They heard a switch go on. A motor started up, and sang furiously higher and higher, until another switch controlled and steadied it. The floor shook with an even vibration. The little red light, at right angles to the ceiling, looked threateningly across at them. Somewhere lightning flashed. And with a milky gleam a window of light emerged from the darkness: it was the square hanging screen, before which Hofrat Behrens bestrode his stool, his legs sprawled apart with his fists supported on them, his blunt nose close to the pane, which gave him a view of a man's interior organism.'[5]

So it must also have been in 1912, when Mann's wife was admitted to a sanatorium in the Alps with vague complaints. And so it was right after the invention by Wilhelm Röntgen – who sought no fame, never wanted to profit financially from his discovery and would die penniless – when hospitals had their own X-ray machines built. Some of these contraptions looked like enormous cabinets you could stand in. They creaked and they popped. Sparks flew around. In that ambience, patients had sometimes to remain motionless for an hour; exposure time was not yet measured in milliseconds.

But the result was awe-inspiring: a print of everything that was or was not well in the body.

Doctors could locate kidney stones, bone fractures and tumours. Dentists could detect dormant cavities between teeth. Spiritualists proclaimed they could photograph the soul. There was a rumour that special glasses allowed for seeing through clothes; one manufacturer advertised women's underwear that protected against this.

The definitive breakthrough of X-ray photography came during World War I. Marie Curie herself used the technique at the battlefront to detect bullets and shrapnel. She had cars equipped with X-ray instruments called *petites Curies*. She trained people, including her daughter Irène, who would take X-rays of countless soldiers to help put them out of their misery. Lise Meitner, the Jewish scientist who pioneered uranium fission with Otto Hahn in the late 1930s [see Chapter 1], did the same work for Hitler's allies in the Austrian army.

Visiting his sick wife in the sanatorium, Thomas Mann saw the thin line between sickness and health, between life and death. What did the nervous Hans Castorp see in *The Magic Mountain*?

> 'And Hans Castorp saw, precisely what he must have expected, but what itis hardly permitted man to see, and what he had never thought it would be vouchsafed him to see: he looked into his own grave. The process of decay was forestalled by the powers of the light-ray, the flesh in which he walked disintegrated, annihilated, dissolved in vacant mist.'[6]

Mann gave a literary twist to the slight panic that overtook Frau Röntgen earlier.

But where they detected death, others noticed life. Even then, radiation was used for more than just taking pictures. A drop of radium was inserted by injection or capsule into patients suffering from everything from tuberculosis to cancer. Even hairy birthmarks were radiated away. Pharmacists sold dozens of medicines with radioactive ingredients. They promised protection against bacteria and viruses, and promotion of blood circulation and sexual energy. In the 1920s and 1930s, it was widely believed that radiation enhanced your health.

Spas, which by now were known to obtain the heat in their natural baths from radioactivity in the soil, became tourist attractions. Joachimsthal, the source of uranium for the Curies' scientific work, attracted thousands of guests from the bourgeoisie in Vienna and Prague every year. Many stayed at the Hotel Radium Palace, where they drank the locally brewed Radium beer in the lobby. One of the guests was Robert Oppenheimer, who, as the 'father' of the atomic bomb, would later say that his interest in science began when his uncle gave him a collection of colourful stones from the Joachimsthal uranium mines.

A craze ensued. Radioactive ingredients were found in soaps, salves, bath salts, face cream and hair growth remedies. You could snack on radioactive chocolate, and then brush your teeth with toothpaste that contained a little thorium, for sparkling

teeth. When Germany began research towards an atomic bomb in 1939, the War Ministry searched for fissile material in a toothpaste manufacturer's landfill.

Radiation was synonymous with modernity. The positive associations – vitality, quality – led to a series of brand names that suggested radiation. Americans bought condoms in packaging that simply said 'Radium'. Meanwhile, doctors tried radium on patients with heart ailments, infections, high blood pressure, epilepsy, headaches, diabetes, arthritis, rheumatism – really, the whole medical encyclopaedia.

In all this optimism, an elixir of life was not inconceivable. An American entrepreneur produced bottles of distilled water with radium, called Radithor, which became a resounding success. 'Certified Radioactive Water' was advertised on the label. According to the salesman – a former Harvard University dropout posing as a doctor – it worked well against pain, asthma, diabetes, constipation, impotence… well, against anything, really.

It also worked well if you wanted your bone tissue to wither away. An avid user, who drank Radithor throughout the day for years, lost his teeth and jaw before holes appeared in his skull. After a long and agonising struggle, he died of cancer in 1932.[7]

By then, the risks of radiation were well known. Victims of overexposure to radiation felt weak, developed cataracts, lost their hair or became temporarily infertile. The damage manifested itself mostly to doctors and their assistants who experimented lavishly without proper protection. Some tested X-ray equipment by holding their arm in front of the screen. Many of their patients benefited from the diagnostic radiation, but they themselves suffered badly. High-dose radiation damages DNA. When proteins cannot repair that damage, cancer can occur.

The risks were also known when luminescent paint was applied to the numerals and hands of watches. US soldiers wore them in the European trenches and millions were sold after World War I. Men and boys in particular found them cool. The dials were painted in workshops where young women were employed who developed all kinds of ailments. Their teeth loosened, and sores appeared on their gums. One felt pain just from touching her face. A dentist pulled out a suspicious molar. A piece of her jaw came with it.

What was going on here?

The magic bullet in the paint was radium, to which chemicals such as zinc sulphide had been added to make it glow. To get the tip of the brush sharper for the delicate drawing on the dial, women put it routinely between their lips. That was how they had been taught. It was no more than a thousandth of a gramme of paint each time, but still a teaspoon a week, a coffee cup a year. Sometimes the women painted their cheeks or teeth, just for fun.

Thus, more and more radium stuck to their bones. By 1923, the first deaths were recorded of a series of workers who would succumb to a new occupational disease: radium jaw.[8]

Employers denied any responsibility. One spread the rumour that the women had syphilis before falsifying a damning report, so that it appeared as if the entire workforce was in perfect health and the workplace was spotless. In reality, everything and

everyone in the workshop gave off light: from the chairs the women sat on to their hair and corsets.

The workers began a lawsuit. Their bosses, it turned out, knew about the dangers and had deliberately concealed them. The legal action was widely reported in the press. Eventually, in 1928, the women were awarded damages. The industry now had to introduce safety procedures and enforce them.

It was a historic victory. The case of the so-called 'radium girls' led to legislation requiring employers, including in other industries, to take safety measures and give workers the right to claim damages for negligence.

At the end of the court case, radiation protection became a scientific discipline with the creation of what would become the International Commission on Radiation Protection (ICRP), an independent organisation that would protect humans and the environment from the harmful effects of radiation by setting standards and making recommendations.

Radiation evokes mixed feelings, then and still today. Both the positive and negative emotions are deeply rooted, as Spencer Weart convincingly described in his cultural history of nuclear power, *Nuclear Fear*. There is a subconscious hope that radiation can work miracles. In folk legends, rays were linked to procreation and healing powers. In religious symbolism, the body of a divine or holy person was surrounded by a halo of rays.

At the same time, there was the age-old dread that radiation posed dangers. It used to be feared that evil spirits could spread their bad influences through rays from their 'evil eye'. Witches could invoke mischief in anyone through invisible forces.

Sometimes the positive and negative emotions surrounding radiation followed each other in quick succession. Thomas Edison, in his time the most famous inventor in the world, with the most patents to his name, saw the potential of X-rays. He had his team work on a fluoroscope, a device that allows you to look inside the body. Clarence Dally, a loyal laboratory assistant, used his left hand for tests and demonstrations. When burns started to appear, he simply used his other hand. The wounds would not heal. At night, Dally slept with his hand in a tub of water against the pain. His facial hair fell out, including the eyebrows and eyelids. His hands swelled. As the cancer crept up, both his arms were amputated. The disease continued to spread until Dally died in 1904.

During his assistant's illness, Edison abruptly stopped working on the fluoroscope which is still used in medical operations today. He wanted nothing more to do with it. When asked in an interview about the situation with Dally, Edison said: 'Don't talk to me about X-rays, I am afraid of them!'[9]

The discovery of radioactivity raised all sorts of unconscious associations. A series of books, comics and films appeared in which radiation bestowed magical powers. This went both ways: unscrupulous monsters wreaked havoc with their deadly rays, but superheroes possessed superpowers thanks to radiation.

This ambivalence was reflected in Superman. His X-ray vision allowed him to see through walls, but he was terrified of the radiation from kryptonite that could incapacitate him.

Our superheroes from Paris, the Curies, developed health problems because of their work with radioactive sources. Pierre sometimes applied radium to his arm to study the burns. At times, he suffered excruciating pain, eventually dying in 1906 when crossing a rain-soaked cobblestone street and slipping, after which the wheel of a horse cart crushed his head. Marie regularly suffered burns on her fingers and hands. After her field work during the war, her cataracts worsened and she became frail. She died of anaemia, perhaps caused by bone marrow failure. Still, Madame Curie lived to be 66, well above the average life expectancy of her time.

Just before her death, Curie was visited by her daughter Irène, who had become a scientist. She had great news for her mother. With her husband Frédéric Joliot, she had bombarded elements with ionising radiation, creating radioactive isotopes. Boron turned into nitrogen, magnesium into silicon, aluminium into phosphorus. Irène Curie and her husband were the first to have deliberately created radioactivity!

The alchemist's dream [see Chapter 1] had come true.

Marie Curie died in a sanatorium in the Alps on 4 July 1934. That day marked a transition in the atomic age: the period of scientific curiosity gave way to one of opportunism. On the same day, in London, the Hungarian intellectual Leó Szilárd [see Chapter 1] filed a patent for the nuclear reactor.[10]

* * *

Since those early experiments with radioactivity, we have come to learn much about it. We know how radiation can be useful in healthcare. Targeted X-rays are used to diagnose all kinds of diseases. With precise equipment, cancer cells are irradiated while healthy cells are left alone as much as possible. Dozens of radioactive isotopes are used both to diagnose and treat diseases.

Medical isotopes to diagnose and treat tumours are made in a nuclear reactor. Their names appeal little to the imagination. Iridium-192 is used to irradiate cancer tumours. Lutetium-177 is for the treatment of metastatic prostate cancer. Molybdenum-99 is the raw material for technetium-99m that controls blood flow in the heart muscle. These and other medical isotopes benefit tens of thousands of patients every day.

Radiation is also used outside the healthcare sector. Older smoke detectors contain americium-241. The green, luminous signs indicating escape routes in buildings contain tritium gas. Space probes and satellites in the solar system are powered by plutonium. The construction of buildings, bridges and aircraft is checked using selenium-75 to detect cracks in materials or failed welds, for example.

Not only do we know more and more about how to put radioactivity to good use, we also know more and more about when it is harmful. When radiation enters the body,

damage can occur to cells and organs. But not all radiation is the same and not all radiation is equally dangerous.

Radiation comes in different types in nature when an atom spontaneously decays, as Ernest Rutherford discovered in 1898. Alpha radiation immediately gives off much of its energy and cannot even penetrate a sheet of paper or the layer of dead cells on our skin.

If alpha rays penetrate the body, after ingestion or inhalation, they damage organs. This happened to Alexander Litvinenko, a critic of Russian President Putin who was poisoned in 2006 when his tea was infused with a large dose of polonium-210.

Beta radiation contains much less energy. Through the air, it barely gets further than a few metres. It passes through paper, but not through an inch of aluminium.

Gamma radiation is an electromagnetic radiation like light, which has much more penetration. Gamma radiation cannot be completely stopped, but it can be very much attenuated. To reduce gamma radiation from an operating nuclear reactor to safe levels, you need thirty centimetres of lead, two metres of concrete or five metres of water. When used in a hospital, a syringe is surrounded by a protective sleeve containing two millimetres of lead.

Radiation and radioactivity can be measured in remarkably many units, such as the roentgen, the becquerel, the curie, the gray, the rem and the rad. To determine the different effects of different types of radiation on humans, the sievert is the most common unit. Named after the Swede Rolf Sievert, who worked at the intersection of physics and medicine, the sievert includes numerous considerations and refers to the 'effective dose' of radiation. This expresses the risk a person faces after receiving a dose. The sievert is on the large side. Therefore, it is usually calculated using a thousandth of it: the millisievert, or mSv.

Now for some figures: how much radiation leads to what consequences? Numbers are important. A famous theorem of Paracelsus, the 16th century physician, alchemist and founder of toxicology, states that the dosage determines whether something is toxic.[11]

When the radiation in our bodies reaches 5,000 mSv, death is a matter of weeks or months in half the cases. A series of symptoms precede it: high fever, internal bleeding, infection, diarrhoea, malnutrition, dehydration. In Hiroshima and Nagasaki, some received as much as 20,000 mSv in one blow. All their body cells died off at breakneck speed. When that happens to nerve cells in the brain, all systems in the body break down. The victims are likely to have welcomed death.

Indeed, Leslie Groves, the military director of the Manhattan Project, was wrong when he declared after the war: 'In fact, they say it is a very pleasant way to die.'[12]

A sudden dose of 1,000 mSv is likely to cause burns. The symptoms of acute radiation sickness are no longer inevitable. The cells in the body are unlikely to die. The body will recover because enough cells are present in the marrow to grow and make blood cells.

Around 100 mSv is the limit at which we reasonably assume damage will occur. That damage manifests itself in cell mutation, a possible harbinger of cancer. Because

there are many causes of cell mutation, and thus many causes of cancer, it is impossible to determine at the individual level whether radiation is the culprit.

Up to 100 mSv, no evidence of permanent health damage has been determined.

As we saw earlier, we need not be near an exploded atomic bomb or nuclear reactor to contract radiation. According to the UK Health Security Agency, residents of the United Kingdom receive an average 2.7 mSv of ionising radiation per year, largely due to natural sources present in the soil since the Earth's creation.[13] Today, they emit their radiation, for example, through the bricks and concrete from which our homes are built. The type of soil also matters: clay and loess contain more radioactivity than sand or peat.

Between countries, there are large differences in this natural background radiation. Outliers include Cornwall and parts of Belgium, Finland and the Czech Republic where large groups of people live with an annual natural radiation dose of 7 mSv.[14] The highest measurements occur among inhabitants of Ramsar, an Iranian city by the Caspian Sea, where thousands of people live with an average dose of 10 mSv, mainly because their houses are built with limestone from the surrounding area. In exceptional cases, measurements reach 260 mSv.

People living in such hotspots do not appear to present health problems more often than those in surrounding regions with lower radiation levels.[15]

Then there's radiation from space, from sources outside our solar system that collide with air molecules in the Earth's atmosphere. In the mountains, radiation from the cosmos is higher than that below sea level. Because we're closer to the cosmos on a plane, we're exposed to radiation every time we fly. A return trip from London to Sydney yields about 0.1 mSv. The annual dose for pilots and flight attendants can be as high as 5 mSv.

Finally, there's the radiation involved in all kinds of medical procedures. A CT scan of the abdomen is about 10 mSv. Four X-rays during a mammogram to detect abnormalities in the breasts bring about 0.6 mSv. When we have a picture taken at the dentist's office, it is about 0.003 mSv. Since Americans and Japanese use these kinds of scans fairly extensively, they get half of their total radiation dose through medical diagnoses and treatments. A rough but controversial maxim is that a dose of 1 mSv leads to an additional risk of one in twenty thousand, or 0.005 per cent, of developing and dying from cancer later in life.

'Sizeable population groups,' UNSCEAR writes, are exposed to 10 to 20 mSv annually from a variety of radiation sources.[16] Studies suggest that our bodies can adapt well to those kinds of doses, although altogether they could contribute to cancer.

Back to Chernobyl. How much radioactivity was released there when one of the reactors exploded? How much radiation did people in and near Pripyat absorb? What about those in Western Europe, thousands of kilometres away?

The figures get a bit murky here. After the accident, employees of the nuclear plant along with firefighters came into contact with different types of radiation in different ways. Staff were covered in radioactive dust from the explosion and splashed

with radioactive steam from ruptured pipes. Some stood ankle-deep in radioactive water, others breathed in radioactive dust. Some dust quickly dissipated, while other particles scorched their airways. There were workers who kept their overalls on all night, leaving their skin irradiated all that time.

Even for local residents, the amount of radiation they received due to the accident is not easy to determine. It matters whether they had the window of their bedroom open or closed at night, whether they went outside or stayed inside the day after the accident, whether they washed their hair and clothes, whether they were outside when it started raining.

Nevertheless, estimates have been made by UNSCEAR.[17] On average, residents of the most affected areas in Ukraine, Belarus and Russia would have received between 10 and 30 mSv – not annually, but added together in the 20 years to 2005. If, added up with other radiation sources, a person thereby exceeds 100 mSv, his or her theoretical chance of a fatal cancer increases by 0.15 percentage points for every millisievert contracted. By comparison, countless residents from Belgium to Brazil to Finland to India are exposed to much more than 100 or even 200 mSv in 20 years of natural background radiation alone.

UNSCEAR mentions that among the hundreds of thousands of clean-up workers in particular, there are uncertainties about the dose they received. For them, the total radiation dose in the years up to 1990 was estimated at an average of 120 mSv. Some 85 per cent of these workers received a dose somewhere between 20 and 500 mSv, with outliers above 1,000. These estimates are on the upper side, according to the researchers themselves.

If UNSCEAR widens the circle to six million residents of areas in the former Soviet Union that were most contaminated, then their average radiation dose in the 20 years since the accident is estimated at 9 mSv. If it expands the circle to all the nearly 100 million people in Ukraine, Russia and Belarus, it ends up with an estimated average dose of 1.3 mSv. UNSCEAR speaks of ‘an insignificant increase over the dose due to background radiation over the same period’.[18]

And the remaining hundreds of millions across Europe? Their total dose of radiation from Chernobyl, over a lifetime, is no more than what nature imperceptibly administers to them every year. In the UK, the Chernobyl accident annually contributes to 0.0054 mSv.[19] That includes fallout from atomic tests.

* * *

As a species, humans have great difficulty in rationally assessing risk. We imagine flying is more dangerous than driving a car. We fear a terrorist attack even though it is more likely that an argument within the family will be fatal to us. Basic knowledge of statistical probability changes little, because we humans are selective in how we process information. Even the mind of the smartest person can be held hostage to incorrect assumptions and irrational fears.

Exposure to ionising radiation leads to illness or death only in highly exceptional situations, but the discomfort is always there. When we are having a scan in hospital, we consciously choose exposure to radiation. That's not the case when an accident occurs in a nuclear plant. Do we know for sure that radioactivity is not escaping from there Experts may be able to measure radiation accurately, but can they be trusted? You and I cannot perceive it. In any case, if effects of radiation ever occur, it will be much later, insidiously. The damage is difficult, often impossible, to determine.

That doesn't sit well with us.

However, there are a few rules of thumb. The body can cope well with radiation. It will undo any damage by itself. Irreversible damage only results from a certain dose that we are unlikely to contract. Radiation is deadly only in exceptional circumstances. When these present themselves, death usually comes later in life, after a common illness – cancer – for which there are all kinds of causes.

All the while, any danger remains hidden from our senses. That sounds scary, but we can also look at it differently. Perhaps, as a radiology expert once remarked, there is a good explanation why we do not have a sensory organ with which to register radiation: we have no reason to.[20]

And yet, that is not the whole story. Health is more than a matter of a functioning body and a beating heart. The radiation released in a nuclear plant accident may not do much to our physical body, but it does all the more to what goes on between our ears. This became apparent when a trembling of the ground signalled the beginning of a new nuclear nightmare for the Japanese...

6. Exodus
What should you (not) do after a nuclear accident?

> 'But as I travell'd hither through the land,
> I find the people strangely fantasied;
> Possess'd with rumours, full of idle dreams.
> Not knowing what they fear, but full of fear'
> – William Shakespeare, *King John*

Satoru Yamauchi misses his noodle restaurant. Upon returning after many long years, he acknowledges it meant everything to him. 'It was my life,' he says.[1] His voice cracks.

It will be hard to start over again. Growing rice or picking wild plants in this area isn't allowed. How should he prepare his famous tempura with seasonal vegetables?

And for whom? Yamauchi doesn't yet see many potential customers in Naraha, the first village in the province of Fukushima to be declared habitable again in 2015, four and a half years after radiation escaped from the nearby nuclear plant and some 160,000 people were forced to evacuate.

Yamauchi will never forget that disastrous Friday in March 2011. In the early afternoon, Yamauchi is working in his noodle restaurant when the ground begins to tremble beneath his feet. It will be one of the worst earthquakes ever measured. Throughout Eastern Japan, buildings shake and collapse. Some people get trapped, others crushed. Gas cookers and power lines break. Fires start.

Then Yamauchi hears a warning: a tsunami is coming. He makes his way out and dashes up the hills. The first waves rushing over the land are ten metres high, much taller than the alarm had announced. The highest is nearly 40 metres. Cars, houses and entire villages wash away.

The force of the natural violence on that cold day is beyond comprehension. The whole of Japan's main island shifts a few metres. The vibration of the seabed reaches as far as Antarctica, where ice mountains break off. All the way on the other side of the Pacific Ocean, off the coast of Chile, the waves are still two metres high. The death toll from the natural disaster on 11 March 2011 will eventually be determined at almost twenty thousand, plus a few thousand missing.

For Satoru Yamauchi, the damage is not too bad, or so it seems. He himself, his wife and their four children are unharmed. Their house on the hillside has not been swept away. Their dog is doing fine. His family is relieved to find themselves amongst the lucky ones.

Soon enough, they don't feel so lucky anymore.

Something is wrong at the Daiichi nuclear plant in Okuma, 20 kilometres away. Sensors have detected the coming of an earthquake in time and the reactors have shut down automatically. However, cooling the fuel rods in the reactor cores is a problem. The power needed to pump water around has failed and the emergency diesel generators in the basement aren't working either due to water damage. The temperature inside the reactors is rising…

Prime Minister Naoto Kan is not sharing any of this information when he appears on TV at around 5 PM. In a brief statement, he expresses his condolences to compatriots who have been affected by the tsunami. Then suddenly, from out of nowhere, he says: 'As for our nuclear power facilities, a portion of them stopped their operations automatically. At present we have no reports of any radioactive materials or otherwise affecting the surrounding areas.'[2]

He asks everyone to remain calm.

Behind the scenes, Kan himself is anything but calm. The head of government, already plagued by political affairs, shouts and snarls at his staff. Fearing the consequences of an overheated nuclear reactor, he keeps saying, to no one in particular, sometimes loudly, sometimes muttering: 'It's the same thing as Chernobyl! It'll be just like Chernobyl.'[3]

While some pray for the nuclear reactor to cool down quickly, a close associate writes in his memo: 'It's Kan who needs cooling down.'[4]

Later that evening, Kan declares a nuclear emergency.

Evacuation orders follow in quick succession. First a two-kilometre radius around the nuclear plant, then 10 kilometres, then 20. Now the Yamauchis in Naraha have to move as well, right now. Buses show up, some with squealing tyres, and everyone squeezes in. This is how Satoru Yamauchi ends up in a shelter. He makes himself useful in the soup kitchen.

The days are full of dread. Workers at energy company TEPCO (Tokyo Electric Power Company), owner of the nuclear plant, are making frantic efforts to bring the situation in Daiichi under control. In the absence of power to keep the cooling system functioning, the water may eventually turn into hydrogen, which can explode. This is what happens. In the following days, there are three hydrogen explosions in the reactor buildings. Everyone sees the footage. Everyone is shocked.

This time it's the Deputy Chief Cabinet Secretary who says: 'Isn't that an explosion like the one at Chernobyl? Isn't the same thing happening that happened at Chernobyl?'[5]

The rising grey cloud is reminiscent of Godzilla, the awakening sea monster.

Rumours start. TEPCO's staff and Emperor Akihito are said to have fled. Someone said someone saw a mushroom cloud. A mushroom cloud? No one in Japan has forgotten the horror of the atomic bomb. *Let's get out of here!*

Roads are jammed with cars. People stuck in traffic have escaped the rushing water, but are now wondering how to elude the mysterious poison in the air. It was said

that most of the radiation was blown towards the sea. But what if the wind turns? What if it starts to rain or snow?

Satoru Yamauchi, too, is in doubt. His children beg him: 'We don't want to die from radiation. Let's go to Tokyo.'

And there, in Tokyo, at a safe 200 kilometres from the nuclear plant that would dominate world news for weeks, their problems begin. Feelings of depression and a lack of purpose bubble up and won't budge. At school, the children are bullied and excluded; they're said to be radioactive. The family also faces financial problems, despite the monthly allowance for all those who had to flee their homes.

Years later, back in Naraha, Yamauchi says, 'Psychologically we were wrecked.' He himself takes pills for high blood pressure.

Like tens of thousands of others, Yamauchi tried to build a life elsewhere, and is now full of doubts upon his return. 'I want my old life back,' he says, 'but I don't think it's possible here.' For him and his family, it feels like they live with a death sentence, marked by the radioactive cloud hovering over them.

The return of the Yamauchis and their fellow villagers to Naraha is possible now that the government has finally lifted the evacuation order. The abandoned areas have now been sufficiently cleaned. The topsoil has been scraped off and put into bags, the earth shovelled over. Houses, offices and streets have been rinsed clean. Leaves have been removed from trees. The cost for the whole province: about 7 trillion yen (more than 40 billion GBP). And the costs are spiralling.

However, while the invisible danger is brushed away, something else just as imperceptible takes its place: suspicion. Is it really safe? Is there really no health risk anymore? What's up with those Geiger counters that the government distributed to all residents so they can measure the radiation level themselves? Have they been tampered with? After all, looking at those meters, nothing much seems to be going on. Are our leaders hiding something?

Satoru Yamauchi also fails to feel relieved. 'There is nothing good about going back.'

If – yes, *if* – nuclear power has a future, much will depend on how we react after a nuclear accident. What happened in Fukushima does not bode well. Naoto Kan got it right: Fukushima became 'just like Chernobyl'. But not quite as he had in mind...

* * *

Just before the Chernobyl disaster was about to be commemorated after 25 years, UNSCEAR, the United Nations Scientific Committee on the Effects of Atomic Radiation, published a report with findings on its long-term health effects.[6] It was published 11 days before the tsunami hit Japan's east coast. Had Kan noticed the report, or someone in his entourage of advisers, he would have known not only that the increase in cancer was very limited – hardly measurable in a large population – but that there was serious psychological damage caused by fear of radiation.

People from the Pripyat area, the authors argued, are much more likely to suffer from stress, excessive anxiety and depression. This affects their behaviour: they drink more, smoke more, eat unhealthier, live more recklessly. The main public health impact of the world's biggest nuclear disaster was not physical, but mental: anxiety.

That conclusion was not new. In 2006, the Chernobyl Forum, a collaboration between various UN agencies and national governments, found that people from the region suffered from an accumulation of complaints. The authors talk of 'an exaggerated sense of the dangers to health of exposure to radiation', and of 'a widespread belief that exposed people are in some way condemned to a shorter life expectancy'.[7] With just about every cough, they started thinking: *oh dear, is this because of the radiation? Is the deterioration starting now?*

Even then, it had been established that, despite the facts, people are convinced all kinds of diseases occur more frequently now and that these must have something to do with radiation. Already in the first months after the nuclear disaster, many thousands of women all over Europe, including in Denmark and Greece, had abortions for fear of what the radiation would do to the foetus.

Louisa Vinton, programme manager at the Chernobyl Forum, once observed: 'Fear of radiation is a far more important health threat than radiation itself.'[8]

After power failed at the Daiichi nuclear plant in Fukushima, it was soon clear that radiation levels were much lower in the surrounding area than at Chernobyl; nobody was hospitalised with acute radiation sickness. After the crash course of the previous chapter, we know all about the millisievert. How many are we talking about in this case? Let's look at figures from UNSCEAR.[9]

In the first year, evacuated Japanese were on average exposed to less than 6 mSv. That's lower than a pelvic CT scan.

Immediately outside the evacuation zone, it was less than 4 mSv. That's pretty much the dose a full-time flight attendant absorbs every year.

In the days following the accident, crowds of expats who wanted to be on the safe side took a plane home from Tokyo, surrounding themselves with more radiation, high up in the atmosphere, than if they had stayed put.

And so it's no wonder that UNSCEAR reports, in its two studies on Fukushima published in 2014 and 2022, that there is no discernable increase in health effects linked to radiation. There is no increase in birth defects or heart attacks. There is no increase in thyroid cancer, leukaemia, breast cancer, colon cancer or any other cancer that can be related to radiation from the Daiichi nuclear plant. Nor does the UN Commission expect such an increase. Indeed, the dose incurred by the population is 'low or very low'.[10]

The dose is higher for those who worked at the damaged nuclear plant. Of over 20,000 people working there in the year and a half after the accident, six exceeded the 250 mSv limit set for emergency workers. Excluding these six outliers, the average dose in the first year hovered around 13 mSv – one chest CT scan and one of the spine. By the second year, the dose had more than halved.

Among aid workers, UNSCEAR doesn't expect to see an increase in health effects related to radiation either. Perhaps some will suffer from cataracts, since not everyone followed regulations and shielded their faces properly while working. Less than two hundred workers were exposed to more than 100 mSv. They now have a slightly higher chance of developing cancer later in life – say, an increase from 30 to 31 per cent. Given the small group of people involved and the relatively high probability of getting cancer anyway, they will not be noticed in the statistics. Whether that is reassuring for them remains unknown.

The scientifically established number of radiation deaths in Fukushima is zero.

A Japanese court ruling in 2018 put the number of radiation deaths at one. It concerned a former employee who had worked in several nuclear plants since 1980, the last few years in Fukushima. According to a provision in the law, his fatal lung cancer could theoretically be attributed to the radiation he contracted there.[11] So: zero in the world of science, one in the world of politics.

By contrast, the evacuation led to many fatalities, and these are hardly disputed.

After the hasty evacuation, intended to keep people safe from the radiation, things immediately went wrong for the most vulnerable. The UNSCEAR report confirms that in the chaos during and immediately after the evacuation, dozens of hospital patients died. Hundreds of elderly people passed away as a result of the abrupt move. Some had not been moved at all, but were accidentally left in their rooms, where they forgot to drink or take their medicine. They dehydrated and wasted away.

According to the Japanese government's definition, nine years after the disaster, the number of deaths due to the evacuation and associated stress was put at 2,313.[12]

In 2016, the World Health Organisation concluded that the Chernobyl disaster's greatest impact on public health was its 'psycho-social impact'.[13] Similarly, Fukushima's accident resulted in more depression, more post-traumatic stress and more alcoholism.

The impact was especially evident among those – both adults and children – who had been evacuated. They were more likely to suffer from obesity, diabetes and high blood pressure than people who had not been moved out. UNSCEAR offers an explanation: they lost their homes, their jobs and their connection to the community.

Once more, similar conclusions emerged from earlier research on Chernobyl, where 350,000 people had to relocate. That experience was 'deeply traumatic', in the words of the Chernobyl Forum.[14] 'Many are unemployed and believe they are without a place in society and have little control over their own lives.'[15] There was said to be a 'paralysing fatalism' among evacuees and residents of areas around the nuclear plant after the Chernobyl events.[16]

People who returned to their homes after some time, against the rules, were considerably happier than those who stayed away. Many journalists discovered this when visiting the Pripyat area. These *samosely* – the Russian name for the people who settled illegally in the inaccessible 'exclusion zone' – often grew food in their gardens, collected herbs from the forest, hunted wild animals and fetched water from local wells. Comprising many hundreds, even thousands, they formed a stiff-necked, now largely

extinct tribe. Their presence was permitted with a blind eye. They often appeared healthier and happier than their former compatriots who could not adjust to life in a different environment, free of radiation but full of worries.

People evacuated after the nuclear plant in Chernobyl exploded suffered the same mental problems, such as stress and depression, observed in those who experienced the atomic bombing of Hiroshima and Nagasaki. But where the Japanese saw themselves as *survivors* at the time, the Soviet people saw themselves as *victims*. That feeling was reinforced by politicians who offered financial compensation to some seven million people, plus an endless list of preferential treatments: from free medicines and dental care to discounts on public transport and holiday vouchers. Many came to see themselves, reports the Chernobyl Forum, as 'helpless, weak and lacking control over their future'.[17]

Those forced to leave their homes after a nuclear accident, Chernobyl or Fukushima, suffered from a stigma: they were excluded and shunned in their new surroundings, sometimes even by their own family. The placement of the evacuees introduced tensions in communities, where there was a perception that they were taking homes and jobs. Many chose not to tell anyone where they came from, making up a family history.

Social exclusion of those who have been in contact with radiation is a well-known phenomenon. The crew of the Japanese fishing boat that fell ill from fallout after a US nuclear test in 1954 [see Chapter 2] were shunned for a long time after their recovery. The *hibakusha*, survivors of the atomic bombings of Hiroshima and Nagasaki, had great difficulty finding marriage partners. Perhaps, it was thought, they gave off radiation. Perhaps their children would be infected and deformed.

Fear of contamination is not confined to Japan. After the Chernobyl accident, some healthcare personnel were apprehensive about treating firefighters and employees from the nuclear plant because radiation sickness was said to be contagious. Local residents who had to evacuate were shunned by their neighbours. Parents did not allow children to play with their peers from Pripyat or sit next to them in class.

It's an irresistible zombie logic – those who are poisoned become poisonous themselves. But radiation does not spread so easily, and certainly not once you've taken a shower and washed your clothes.

Such misconceptions aren't harmless. For instance, Kai Watanabe, a twenty-something who signed on for clean-up work at the Daiichi nuclear plant, believes he will probably not be able to get married. After all, if he ever meets the woman of his dreams, he will have to one day confess to her what he has done for work. 'And what woman would accept it?' he wonders.[18]

Studies show that more than 40 per cent of young mothers in Fukushima have strong feelings of anxiety because of the stigma, and that young women have negative feelings about the prospect of pregnancy.[19]

If the tsunami drew a disturbing trail of devastation, the nuclear accident drew a devastating trail of disturbance. In our minds, these traces soon became mixed up, just as atomic bombs and nuclear power plants were once confused.

It must have been hard to swallow that a modern, advanced society could be so overwhelmed by nature. Politicians realised that although they had not been able to protect their citizens from a tsunami, they could still safeguard them from being exposed to radiation from a damaged nuclear plant. And so the Japanese began to worry about all the terrible diseases they might contract because of the nuclear accident.

Only a few wondered why so much attention was paid to Fukushima's nuclear plant which, like so many other buildings, was not adequately protected against the tall waves, even though there had not been a single fatality at this nuclear plant, unlike all those apartments and offices where many were killed instantly.

In fact, why were thousands of Japanese not better protected from the waves?

* * *

It's only fitting in the incredible story of nuclear power that the Fukushima accident should have come at such an unfortunate time. In politics, the problem of climate change had finally sunk in. Slowly, the realisation dawned that a source of reliable, round-the-clock carbon-free energy could be useful. Didn't nuclear energy deserve another chance? Chernobyl was already so long ago. Surely those old-fashioned Soviet reactors had long since ceased to exist?

Lobbyists for the industry already spoke of a 'nuclear renaissance'. This was rather premature; global electricity production from nuclear plants was no longer increasing, but fluctuating up and down. More nuclear plants were closed than opened.

But a turnaround was in the air. The promise of nuclear power had been discovered by authoritative figures from the environmental movement. Some of them used to dislike it, such as Stewart Brand, a pioneer in the 1960s counterculture, and Stephen Tindale, a former chairman of Greenpeace. They remained enthusiastic about solar panels and wind turbines, but realised, in Tindale's words, 'that renewable energy cannot expand quickly enough to phase out fossil fuels and protect the climate'.[20] They did not want to bet on it, acknowledged their misjudgement and showed a willingness to accept nuclear power.

Fukushima did not necessarily put an end to that willingness. Indeed, some took up the accident as an argument in favour of nuclear power. Ten days after the accident, George Monbiot, one of the intellectual forerunners of the green movement, wrote in *The Guardian*:

> 'A crappy old plant with inadequate safety features was hit by a monster earthquake and a vast tsunami. The electricity supply failed, knocking out the cooling system. The reactors began to explode and melt down. (...) Yet, as far as we know, no one has yet received a lethal dose of radiation. (...) The crisis at Fukushima has converted me to the cause of nuclear power.'[21]

Most drew a different lesson. According to them, it had been proven that an accident could not be ruled out and that nuclear power is therefore unacceptable. Satoru Yamauchi, the noodle restaurant owner in Naraha, is adamant: 'There's absolutely no need for nuclear power. With just one mistake, terrible things happen.'

The leader of Europe's largest economy sided with the chef. Angela Merkel immediately closed seven nuclear plants in Germany. Encouraged by a mass protest, for which 200,000 Germans took to the streets, and referring to an old promise – made when the Greens formed the government together with the Social Democrats – the Chancellor decided to phase out nuclear power. At the time, nuclear accounted for some 25 per cent of all electricity. The last nuclear plant would have to close by 2022 at the latest.

Germany was not alone. Switzerland decided not to build any more nuclear plants. Italy spoke out, once more, against having a nuclear plant within its borders in a referendum and remained a leading importer of power from French and Swiss facilities. South Korea and Taiwan also referred to Fukushima when announcing nuclear power would be phased out.

Japan itself decided all nuclear plants had to close down. The island nation that once opted for nuclear power, because it had exhausted its own coal reserves and didn't want to be dependent on other countries, closed dozens of nuclear reactors. Thus, Japan became one of the world's largest importers of natural gas and coal.

So much for the nuclear renaissance.

As it happened, it wasn't the physical health of the Japanese that took a hit from the events at Fukushima, but the nuclear industry.

Japan's nuclear industry had it coming. For instance, nuclear companies in Japan maintained a close relationship with the regulator. They assigned jobs to one another. Power company TEPCO had been urged to raise the sea wall of its Daiichi nuclear plant, but then did nothing and got away with it.

Japan's nuclear clique proved complacent, even though there had already been fatal accidents: in 1999, two radiation deaths at a uranium processing plant in Tokaimura, and in 2004, five fatalities resulting from a hot steam leak in the turbine building of a nuclear plant in Mihama. In both cases, safety regulations had not been followed. Staff, including managers, were inadequately trained.

Politicians were equally ill-prepared for an accident. There was an occasional mandatory drill, during which officials pretended something serious had happened at a nuclear plant. There was one five months before the ground started shaking in 2011. Then too, Prime Minister Naoto Kan 'declared' a nuclear emergency. Sitting at a conference table with a few ministers, he seemed uninterested, reading text from a stack of papers. *What a waste of time*, thought one of the ministers. After an hour, he angrily said to Kan: 'This serves no purpose.'[22]

Clearly, anyone who believes everything at their nuclear plants is just fine, as the Soviets and the Japanese thought, is at a disadvantage. Safety culture fails when nobody

is concerned about safety. In retrospect, this is an easy observation to make. Such problems should be identified and addressed with foresight, not hindsight.

In both politics and the nuclear industry, there can be a worrying surplus of trust; in society, there has been a serious deficit. This is not surprising. Inside and outside Japan, there is deep suspicion of companies and organisations involved in nuclear power. TEPCO did nothing to correct that image, keeping quiet in the first hours after the accident in Fukushima. Its top executives couldn't be reached; presumably they wanted to shift responsibility for what happened at the plant to the government.

Whatever TEPCO might have said, nobody would have bought it. It would have always sounded like an attempt to cover up the truth. Communication skills are not really their thing. To a journalist's simple question of whether or not there was a meltdown, TEPCO's spokesperson replied that there was 'no evidence to specifically assert or determine either way'.[23]

The provision of information continued to go wrong. Leaving any room for ambiguity leads to questions and concerns. After Fukushima, the Japanese government spokesperson emphasised there was 'no immediate impact' on health.[24] It was meant as reassurance, but anyone hearing the phrase would think: *Ah, so the health impact will come later!*

So when Rafael Mariano Grossi, Director General of the International Atomic Energy Agency, was asked about Fukushima on a stage at the 2021 UN Climate Change Conference in Glasgow and said that nobody had died from radiation, a sceptical audience began to chuckle. 'I don't know why you're laughing,' Grossi responded in surprise. 'It's a fact.'[25]

A fact it is, indeed. But when facts run counter to our thinking, things can get tricky. We have made nuclear power a spectre for so long that deep down we are convinced any accident in a nuclear plant must be of apocalyptic proportions. The mundane reality is nothing like the wild fantasies we have put into our heads.

* * *

Fukushima was the first nuclear accident in a modern society with news 24/7. Back in 1986, we had no images or footage of Chernobyl. Journalists encountered a wall of secrecy. But now, 25 years later, the moment had finally arrived! As if the natural disaster was not enough, there had to be a nuclear catastrophe too.

Anyone re-reading news reports from those early days will be struck by the constantly lurking danger. The reactors spew deadly radiation. Radioactivity keeps rising, well above safe limits. A catastrophe is inevitable. The population seems doomed. It's implied that the Japanese will be felled by cancer in droves, that emergency workers in and around the nuclear plant face certain death, and that authorities in politics and industry are hiding a terrible truth.

Experts with more nuanced analyses were also featured. 'No Chernobyl is possible at a light water reactor,' explained a Japanese professor.[26] 'Loss of coolant means a temperature rise, but it also will stop the reaction.'

Yet such words proved to have little appeal. Journalists noticed what visitors to news websites were more eager to read and share – stories about experts who believed current events in Fukushima were 'worse than Chernobyl'.[27] One, Arnold Gundersen, a retired employee in the nuclear industry, told Al-Jazeera of 'the biggest industrial catastrophe in the history of mankind'.[28]

Editorial choices can lead to a curious cycle. First, journalists spread panic. Then, they turn the panic itself into news. Illustrative of this is the coverage in *The Sun*, the UK's biggest-selling national newspaper. A few days after the devastating tsunami, *The Sun's* editors put the famous yellow-and-black symbol for radioactivity on the front page, alongside a headline screaming: 'Exodus from Tokyo – 1000s flee poison cloud'.[29]

No explanation was given in the paper as to how exactly such a 'poison cloud' could threaten Tokyo's 13 million inhabitants; even according to the most pitch-black doomsday scenario, no such thing was possible. However, the newspaper did manage to report that radiation around Fukushima was already approaching the level where people vomit uncontrollably, hair falls out and cancer rates skyrocket. *Panic!*

The next day, *The Sun* runs an op-ed by Brian Cox, a former pop musician turned professor of particle physics who hosts a popular TV show on science. Cox acknowledges that damage to a nuclear reactor sounds scary, but points out that such a reactor cannot explode like an atomic bomb, and that this Japanese plant is not like the one at Chernobyl. In the steam released into the air, Cox explains, there are only small amounts of nuclear material. 'The levels of radiation released in this way are very small – probably about the same as you would expect on a long-distance transatlantic flight.'[30] *Don't panic!*

But then, two days later, *The Sun* publishes a report by a British expat: 'My nightmare trapped in City of Ghosts'.[31] She is talking about Tokyo. She writes that radiation levels have already increased tenfold. The city streets are grimly empty. It's like a zombie movie, she says. 'What if, every day, radiation continues to double?'

Fear sells, and after a nuclear accident fear abounds. In the 1979 Three Mile Island accident, nobody was injured or made ill; the radiation released to nearby residents amounted to 0.08 mSv, or two X-rays of both hands. Still, America's best-known news anchor addressed the nation with these words: 'The world has never known a day quite like today. It faced the considerable uncertainties and dangers of the worst nuclear power plant accident of the atomic age. And the horror tonight is that it could get much worse.'[32] When it soon turned out things weren't that bad, the tone changed little.

A nuclear accident is a goldmine for the news industry. After Fukushima, journalists stuck to their disaster-laden script. Modern society's free press jumped on the facts as smoothly as the Soviet state broadcaster.

In the Netherlands, journalists looking for context turned to Wim Turkenburg. In the early 1970s, Turkenburg teamed up with an anthroposophical teacher and other kindred spirits [see Chapter 3] to advise the government against building nuclear plants, before co-founding and chairing the *Bezinningsgroep Energie* (Energy Reflection Group),

which, according to its own website, is 'closely linked' to the rise of the Dutch anti-nuclear movement.[33] After Fukushima, Turkenburg became a media personality – not as a co-founder of the anti-nuclear movement, but as a professor of science, technology and society at Utrecht University.

On the same day that Professor Cox provides a nuanced explanation in *The Sun*, Professor Turkenburg is a guest on public broadcaster NOS. 'Energy expert', it reads at the bottom of the screen. Turkenburg calls the situation in Fukushima 'extraordinarily serious'.[34] After all, he says, a radiation level of 4,000 millisieverts per hour had been measured somewhere, and if we then consider that an ordinary citizen is only allowed 1 extra millisievert per year, then, yes, it is 'extraordinarily worrying' if somebody would be exposed to such level of radiation. According to Turkenburg, we can assume that employees there are contracting 'all kinds of radiation diseases'.

But, the news anchor counters, the Japanese government's announcements are somewhat reassuring?

Not so, because Turkenburg gets very different information 'through other channels' and finds it all 'very confusing'.

So what is his advice?

'Evacuate. Fifty to eighty kilometres.'

Should the staff at the nuclear plant also leave?

The energy expert searches for words. 'Well,' he begins, 'one could also say: *I will sacrifice those people*.'

The next day, Wim Turkenburg is back in the studio.

All the news and commentary on Fukushima was so saddening that some could not see a glimmer of hope. On 24 March 2011, two weeks after the accident, Hisashi Tarukawa, a farmer from Sukagawa, 60 kilometres from the nuclear plant, heard he could no longer sell his rice, cabbage and other crops because of the increased radiation. He hung himself from a tree in his field. His son found him.[35]

Tarukawa may have been the first in a long series of suicides linked to events at the Daiichi nuclear plant.

Like Hamako Watanabe, who had to leave her home. In June 2011, she returned, doused herself with petrol and set herself on fire. When she was found missing, her husband discovered her charred body at their chicken farm.[36]

A dairy farmer left a message for those left behind: 'If only there wasn't a nuclear power plant.'[37]

A 93-year-old woman, in the note she left: 'I would only slow you down. I will evacuate to the grave.'[38]

By 2017, 99 suicides had been counted relating to Fukushima.[39]

After Three Mile Island, Chernobyl and Fukushima, we know better exactly what goes wrong when something goes wrong. Even at modern nuclear plants, radiation can escape. The radiation will rapidly decrease; the substances with the highest radioactivity decay in a matter of seconds, minutes, hours or maybe days. For nuclear

plant employees who remain to keep things under control, radiation may have an impact later in life. The effect of radiation on public health is so small that it cannot be measured.

With some straightforward advice for people in the region, the response to the situation is quite manageable. Stay indoors. Close the windows. Wash your clothes. Take a shower.

The government will have to take measures: start advising whether and how to use iodine tablets (so that children in particular can saturate the thyroid gland before radioactive iodine from the nuclear plant accumulates here), monitor or confiscate local dairy products for a month or two. That's about it.

If information is not enough to counter fears, maybe it's time for exceptional measures. An international commission of experts is on standby as an advisory body in any nuclear accident, but should it perhaps take over control of the crisis from the national authorities? And shouldn't those foreign experts then take up residence in the villages surrounding the nuclear plant, preferably with pregnant wives and children, and while we're at it, shouldn't we bring in the country's Prime Minister's family as well?

Could such symbolic gestures ever win the trust that the nuclear industry has long since lost?

A nuclear accident generates quite a bit of uncertainty, which can easily turn into fear. It takes little more than overly firm politicians, failing communication managers, excited journalists and confused experts to do so. They fuel a persistent feeling that disaster strikes when something goes awry at a nuclear plant.

We'll have to learn to live with the fact that a nuclear plant accident cannot be ruled out. It will take a whole lot more than a leaking pump, a crack in the concrete or an inattentive employee, but the risk will never be zero.

When something goes wrong at a nuclear plant, things presumably go wrong at newsrooms too. Yet another gas explosion or another flooded coal mine will not make journalists run faster. It is precisely because nuclear accidents are so rare that they are so newsworthy.

It wouldn't hurt if editors looked at credentials when selecting experts. Because they do exist: competent experts with a good track record and respect from academia. Those who looked carefully could find them soon after the events at Fukushima. After readers of *The Sun* learned of a nervous compatriot's nightmare in Tokyo, they could turn on Channel 4 and come across Geraldine Thomas, an expert on Chernobyl and cancer, and author of several scientific studies on radiation and health. She explained that the radiation in Fukushima did not seem too bad, that any health risk would at most apply to the unfortunate emergency workers at the nuclear plant, and that it would be enough to evacuate only those in the immediate area.

'One thing we should have learnt post-Chernobyl', Thomas continued, 'is not to spread panic and make claims that turn out to be wrong. The psychological damage being done now to the Japanese is huge.'[40]

Meanwhile, in the Netherlands, Wim Turkenburg was all over the news. His university took note, and boasted on its website that Turkenburg was 'the face and

voice' of public broadcaster NOS for about two weeks.[41] In fact, it had become 'impossible to imagine the NOS studio without him'.

Then follows an interesting peek behind the scenes of journalism. The news desk of the Dutch broadcaster had initially invited Tim van der Hagen, a professor of nuclear reactor physics, serving Delft University of Technology as dean of the faculty of Applied Sciences, as well as director of the Reactor Institute Delft, a knowledge centre on radiation. It was informative television, indeed, but the editors weren't happy. They had watched foreign news programmes and the accident sounded much more exciting there. And so the morning after the event, Turkenburg's phone rang. It was the NOS Evening News. Turkenburg summarised the problem: they found that Van der Hagen was 'very reassuring'.

Turkenburg couldn't agree more. 'I had also heard him, and I was not happy with his statements,' he confesses on his university's website. And so Turkenburg was asked if he might want to come to the TV studio to educate the Dutch viewers on Fukushima? He considered it his duty.

In March 2021, as the media looked back in detail at the events of ten years earlier, researcher Mirjam Vossen noticed something after studying 35 articles from Dutch newspapers: almost all were about the aftermath of the nuclear plant accident; the natural disaster was covered 'at most in passing'.[42]

Journalists spoke to people who lived near the nuclear plant and had to move. Not one reporter paid attention to those who had lost loved ones in the natural disaster. Reports and interviews never came from areas further away, where the tsunami had hit much harder. By the way, closer to the epicentre there were a number of nuclear plants. Nobody ever heard about them because those facilities had not caused any problems.

'One-sided and misleading,' Vossen judged. The media researcher must have been in an amiable mood.

In the festival of flaws, the trophy went to... the NOS Evening News. The anchor managed to mix up the sequence of events: 'Ten years ago was the nuclear disaster in Fukushima, Japan, followed by a tsunami.'[43]

It was of all media outlets *De Telegraaf*, known as the most sensationalist tabloid in the Netherlands, that offered context and perspective by interviewing Geraldine Thomas. She aptly summarised the scientific consensus: 'Nobody died from radiation released in Fukushima, and nobody will die from it.'[44]

And then there is the evacuation. The International Commission on Radiological Protection recommends evacuation in case of additional exposure to 100 mSv in an emergency situation. This was not the case at Fukushima. The Japanese government lowered that standard to areas where the annual dose of radiation in the air, just above the ground, amounts to 20 mSv: a level you would be exposed to if you were outside 24 hours a day.

Now those in power could *do something* and start moving out hordes of people.

The appetite for evacuation was insatiable. Even from areas that remained below the new standard, people were forced to relocate. As late as June 2011, when it was long

since clear that the darkest scenario had not materialised and the radiation level was already falling on its own, people were summoned to leave. Not all were able to stay in the Fukushima province, which is larger than half of Wales. Some had to move again and again, endlessly dragging themselves from shelters to temporary housing.

Vast areas were declared uninhabitable due to a radiation level that countless people in Finland, the Czech Republic, England, Brazil, China, India, Australia, Iran and numerous other countries live with on a daily basis without any adverse health effects.

The Japanese government stipulated that residents could not return until the annual radiation dose did not exceed 1 mSv above the previous level after the clean-up. If it were really only safe to live below the new radiation level at Fukushima, many millions of people around the world would have to move.

According to conventional models, a little extra radiation can slightly increase the chances of one day dying of cancer. From 100 mSv, 1 extra mSv is estimated to mean an extra risk of 0.005 per cent. Then it takes 20 years before the chance becomes 0.1 per cent, on top of the normal chance of about 30 per cent.

Probability is complicated for many people. All those percentages... We can also calculate the harm to our health in the number of days we would die prematurely. One can use mathematical models to work out how many days life is shortened on average, for example if we smoke, eat fatty foods or live in a city with a lot of air pollution. The same can be done for exposure to a certain dose of radiation. It's equally possible to calculate how many days life is extended by avoiding radiation through relocation.

For example, the inhabitants of Tomioka, the village near the nuclear plant with the highest radiation levels, who were less exposed to radioactive particles thanks to the evacuation, extended their lives by two months, three weeks and one day.

For other areas, it was less. Thanks to their evacuation from Naraha, noodle restaurant owner Satoru Yamauchi and his fellow villagers extended their lives by no more than a few days.

The figures come from Philip Thomas, a professor of risk management at the University of Bristol. He led a study conducted by a number of universities. The conclusion: the evacuation at Fukushima was excessive.[45] He wants to prevent the Japanese government's response from becoming the prevailing policy choice after a nuclear accident.

According to Thomas (no relation to Geraldine), it is defensible to evacuate the immediate area after a nuclear accident – say, a radius of a few kilometres around the plant. But after a few days or at most a few weeks, everyone should be able to return; a short evacuation has the least impact on well-being. The longer it takes, the greater the disruption.

In 2019, the International Commission on Radiation Protection (ICRP) ruled that an evacuation should preferably be limited to a week.[46]

What to do about the impulse to run? Philip Thomas has a radical plan: provide information. With information – about what radiation is and what it does, about the doses and the millisieverts, about the effects on health and longevity – people can make their own choice whether to stay in the area. If they want to leave, there should be a

financial settlement: not a monthly payment that could lead to dependency, but a decent, one-off compensation.

'With hindsight, we can say the evacuation was a mistake,' Thomas said in an interview.[47] 'We would have recommended that nobody be evacuated.'

Nobody.

What to do when it becomes clear that the accident turned out differently than you expected? What if you realise that 120,000 people had to move unnecessarily and that they have lived in uncertainty for years, that their lives have been severely disrupted, their health undermined?

What if you were among the experts or journalists who appeared to know so well what was going on? What if you were in government when all of this happened?

What if you were the Prime Minister of Japan at the time?

Naoto Kan said in 2016, five years after stepping down, that the situation in Fukushima was so dire that he had considered martial law. 'The future existence of Japan as a whole was at stake,' he said weightily.[48]

Kan considered evacuating a 250-kilometre radius, including the metropolis of Tokyo. The moment almost came when he had no choice. It was only a hair's breadth away, Kan said, and it was all thanks to the courage of his people who risked their lives to contain the nuclear plant, indeed, to save their country.

Truly, it was tremendously clever how he had averted an almost inevitable catastrophe.

Nuclear power? Naoto Kan wanted no more of it. 'Next time, we might not be so lucky.'

Indeed, with such politicians, journalists and energy companies, how lucky people like noodle chef Satoru Yamauchi have been.

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Prologue – Rebellion

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4 – Doomed

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5 – A strange glow

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6 – Exodus

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