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China's nuclear future

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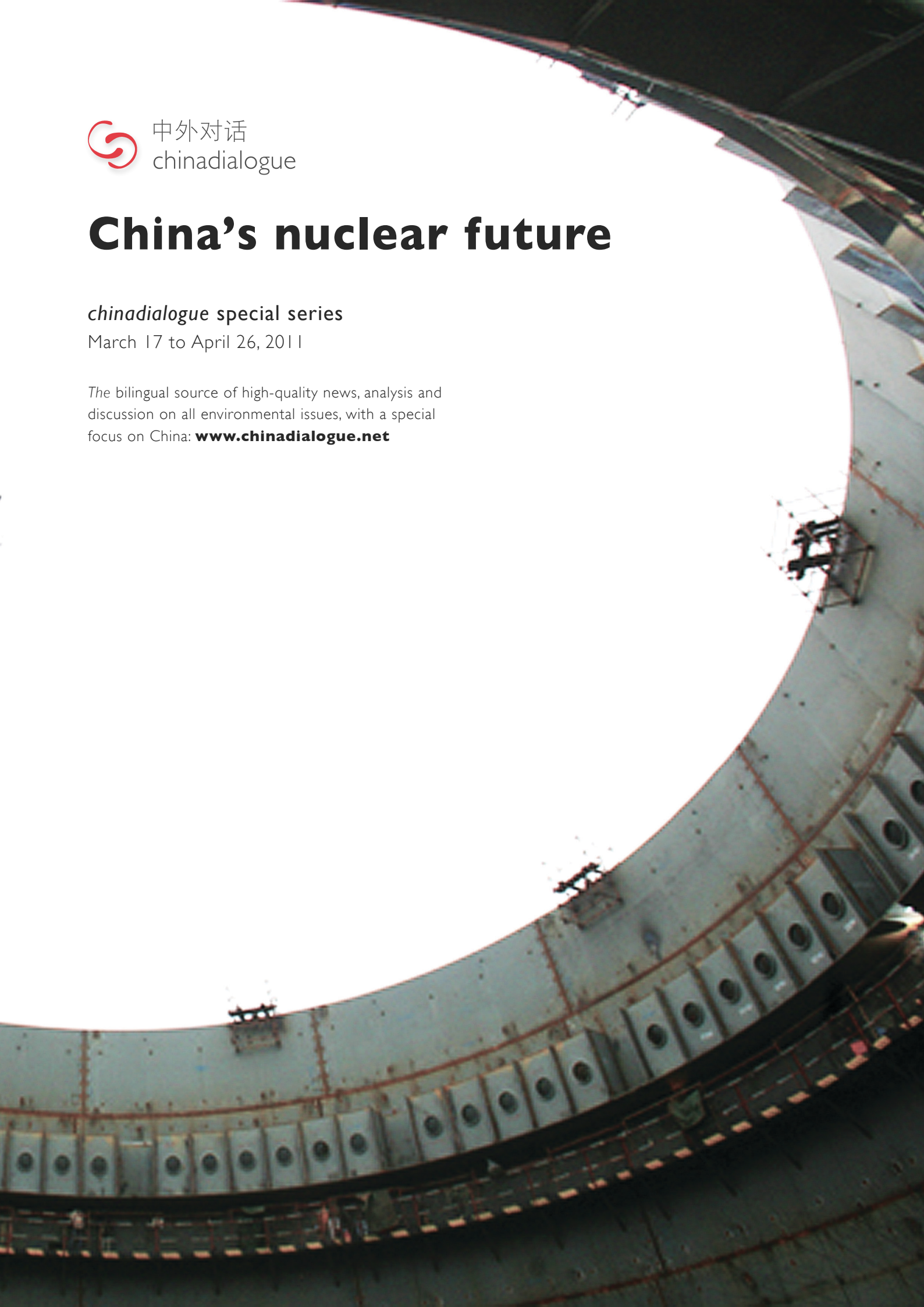

SPECIAL SERIES

China's nuclear future

March 17, 2011

What next for Chinese nuclear?

The world is struggling to respond to the Fukushima radiation disaster – not least in China, the linchpin of the much-hyped nuclear renaissance. ***Antony Froggatt*** *reports.*

Image from DigitalGlobe shows the Fukushima nuclear plant in Japan.

The earthquake and tsunami in Japan have caused unprecedented problems for the country's nuclear industry and the Fukushima power plant in particular. While the environmental impact may be largely national it is clear, even a few days after the accident, that it will have global ramifications for the nuclear industry.

These impacts are not likely to be uniform, however, and variations from country to country will arise from a variety of factors, such as the level of public involvement in the planning processes, the ownership of the energy industry and the local geographic and seismic conditions and risk perceptions.

Within the European Union, Germany has already said it will review its recent decision to extend the operating lives of its reactors and has ordered the temporary closure of the seven oldest, while Italy and Poland have stated that they intend to proceed with their plans. In India, the chairman of the Nuclear Power Corporation, the public body in charge of the design, construction and commissioning of nuclear plants, has said that the events in Japan have put "a big dampener" on their programme. While in Malaysia, the deputy prime minister has stated "we have an agency that is responsible and we are confident that they will implement what is best."

In China, in a remarkable move, it was announced on Wednesday, March 16 that the authorities will suspend approving new nuclear projects until new safety rules are ready, although they did not say when these rules will be approved. The central role China has marked out for itself in the development of the global nuclear industry lends this decision international significance, and it is worth taking a moment to look in detail at the country's nuclear pipeline and what is now at stake.

> *While China is on the forefront of the deployment of nuclear technology, it is yet to show the same determination for implementing international treaties and norms.*

China came relatively late to the civil nuclear industry, only starting construction in 1985. This was after the global peak: thanks to accidents at Three Mile Island (1979) and Chernobyl (1986), coupled with electricity market liberalisation and the wider availability of cheaper natural gas, 1984 was the high water mark for new reactor construction projects around the world. That year, there were 33, compared with an average of only four per year over the last two decades. In 2002, the number of operating reactors peaked at 444.

As of January 2011, there are 441 nuclear reactors in operation. Of these, China has just 13, which provide less than 2% of the country's electricity – the lowest percentage contribution of any country with nuclear power.

Despite, or maybe because of, its late arrival in the nuclear field, China now has an impressive recent history of construction starts. In 2010, it completed two new units (out of five globally) and started nine (out of 14 globally). It plans to continue the pace

of new construction and the 12th Five Year Plan is anticipating 43 gigawatts of reactor capacity in operation by the end of 2015. Meeting this target will require the completion of all the reactors currently under construction, plus a handful more – presumably those ordered in the first half of 2011.

In any other country, it would be hard to believe in such a timetable. But recent construction times of four and half years make the target tough but just about credible. However, concerns have been raised about the impact of such rapid construction on supply chains and the availability of qualified staff. A research unit of the State Council, China's highest administrative body, was reported as suggesting that the rate of growth should be limited.

And, although to date public acceptance has not been a major obstacle to nuclear deployment, this cannot be taken for granted. In particular protests against the Daya Bay facility have historically occurred in Hong Kong both before and after the transfer of sovereignty to China. In other parts of China too, protests are said to have delayed at least one new project. With new reactors proposed in up to 16 provinces, wider public engagement was likely even before the dramatic events in near neighbour Japan.

Meeting the 2015 target would increase nuclear contribution to electricity supply to around 5% and 3% of primary energy. And beyond that, China has proposed installed capacity of around 80 gigawatts by 2020. If achieved, that would give China the second largest installed capacity, behind only the United States.

While these potential deployment rates are impressive, China's importance in the global nuclear sector is not just about construction numbers, but also the types of reactors being built. The world's major reactor vendors, including French company Areva and US-based Westinghouse, are building their most advanced designs in China. In the case of Westinghouse, the AP1000 is the company's flagship Generation III design and China is currently its only sale. Although the specific terms were not disclosed at the time of the announcement in July 2007, the deal was said to be worth around US$5.3 billion (34.8 billion yuan). One of the key factors in the contract was that it contained not only technology transfer for the reactor but for the back end services – namely, waste management.

Not to be outdone, in November 2007 Areva announced the signing of a □8 billion (US$11.2 billion) contract with the China Guangdong Nuclear Power Corporation (CGNPC) for two of its European Pressurized Water Reactors (EPR), to be built in Taishan, Guangdong province. At the signing of the deal, Areva stated that this would result in the deployment of the world's third and fourth EPRs, after those being built in Finland and France. However, construction problems at both of these sites may lead to China hosting the world's first EPR.

At the same time, an agreement has been signed between China and France which opens the way to industrial cooperation on nuclear waste. Under this agreement, the partners agreed to undertake feasibility studies related to the construction of a spent fuel reprocessing plant in China. The 800-tonne per year reprocessing plant will apparently be at Jiayuguan in Gansu province. In November 2010, an industrial agreement on this was signed, which Areva said was "the final step towards a commercial contract" for the project, which is expected to take 10 years to design, construct and commission.

China is also building reprocessing plants with domestic technology. In January 2011, state broadcaster CCTV ran a news item "announcing" a breakthrough in reprocessing at the small, pilot plant in Lanzhou, western China. It is unclear what the specific breakthrough was, given that the plant was completed six years ago, though there has been speculation linking it to ongoing uranium-supply negotiations. What is clear, however, is that China is actively obtaining the equipment for the full range of nuclear technologies – including plutonium-fuelled reactors – as options for the future.

To fuel the country's growing reactor fleet, various Chinese enterprises have been actively purchasing options for the supply of uranium. CGNPC signed a 10 year deal in November 2010 for the supply of 24,200 tonnes of uranium from Kazakhstani nuclear firm Kazatomprom and, in the same month, a similar deal with Areva. In addition, CGNPC and Chinese equity funds each have a 24.5% share in Areva's mines in Namibia, South Africa and the Central African Republic, capable of providing an additional 40,000 tonnes of uranium by 2022. CGNPC also signed a deal in November 2010 with Cameco of Canada for the supply of 13,000 tonnes of uranium through until 2025.

While China is on the forefront of the deployment of nuclear technology, it is yet to show the same determination for implementing international treaties and norms. Although China has signed and ratified the International Atomic Energy Agency's Convention on Nuclear Safety, it is yet, as required by Article 5, to submit its national report on the measures it has taken to implement the obligations of the Convention. China has also become a signatory to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, but has yet to make public its national report. Providing information – both national and international – on safety and waste-management practices are important aspects of a transparent and ultimately a safer nuclear sector.

For over a decade, supporters of the nuclear industry have stated that there is a global renaissance and that concerns over security of supply and climate change will lead to new orders. However, this revival is yet to materialise and events in Japan may make it significantly less likely [see *chinadialogue* article "The nuclear decline" for more on the nuclear renaissance myth]. In the United States, for example, only five years ago Dennis Spurgeon, assistant secretary for nuclear energy at the US Department of Energy, stated it was conservatively estimated that 20 new reactors would be in operation by 2020. Today, predictions are at best for a quarter of this. In Europe, meanwhile, the only two reactors under construction are both behind schedule and over budget.

In fact, excluding China, there has been a net decrease of four reactors on the global grid over the last five years. While the number of reactors coming online will increase, this is in the main due to the industry in China, which has contributed over 60% of the global total since 2006.

The arguments for nuclear expansion in China may be compelling: rapidly rising energy demand, over-reliance on coal and its reserves – located away from primary electricity demand – and economic and political concerns over dependency on imported fossil fuels. However, the history of the global nuclear industry is testament to how quickly public opinion and political support can change as a result of technological failures and accidents, often caused by too rapid expansion.

With the final environmental, economic and industrial impact of the accidents at Fukushima still unclear, it is too early to say how this will affect the global nuclear industry. However, it is doubtful that any country's nuclear programme – including China's – will be fully immune to its consequences.

Antony Froggatt is a senior research fellow in the energy, environment and development programme at Chatham House – The Royal Institute of International Affairs.

March 21, 2011

China's nuclear-waste rush

A 200-billion yuan nuclear scheme could turn a remote spot in western China into Asia's uranium-recycling hub. But is it the right move? ***Yuan Ying*** *and* ***Wang Haotong*** *report.*

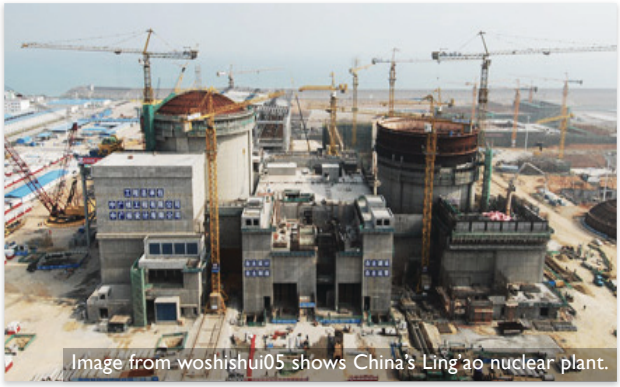

Image from woshishui05 shows China's Ling'ao nuclear plant.

Behind the local government premises in the city of Jiayuguan stands a nondescript six-storey building. A plaque on the door announces it as the planning office for China National Nuclear Corporation's (CNNC) spent nuclear fuel reprocessing facility. Pointing to the building, a local official boasted: "Once that's finished, there will be no limit to growth here."

The "that" in question is a uranium-recycling project worth 200 billion yuan (US$30.4 billion). In November 2010, CNNC and French firm Areva signed an agreement to build a plant capable of handling 800 tonnes of spent fuel here in Gansu province, north-west China.

A number of experts involved in selecting the location for the plant, which plans to recover uranium for reuse, have confirmed that Jinta county, to the north of Jiayuguan, has been chosen. Given that nuclear facilities are required to be sited away from residential areas, if the scheme goes ahead (last week China suspended approvals of new nuclear projects, following Japan's nuclear disaster at Fukushima) its employees will be located outside the county, but still nearby – in Jiayuguan, or the cities of Jiuquan and Yumen.

And so this massive project has caused something of a stir in these small and remote Gobi cities.

These places are sparsely populated, lack resources and rely on a limited range of industries to provide employment. The jobs and investment that come with a project worth hundreds of billions of yuan is just the lifeline they've been hoping for.

Jiayuguan has a brand new airport terminal and is in the process of building a high-speed rail scheme. These were in part made possible by the area's nuclear promise: "Mentioning that project was really helpful when we were applying for the money and land," a local official told us.

Nuclear dilemma

The safety and environmental risks of nuclear power have long been points of controversy – controversy that has escalated in intensity in the week since a major earthquake in Japan triggered a series of explosions and radiation leak at the country's Fukushima nuclear plant. Since the world's worst nuclear accident at Chernobyl in 1986, there has also been constant opposition to the processing of nuclear waste.

> *In 2009, the Chinese nuclear-power sector witnessed South Korea's success in exporting nuclear plants to the United Arab Emirates and became keen to do the same – to sell nuclear services to other nations.*

In early November last year, a train carrying 123 tonnes of highly radioactive waste left France en route for Germany. Almost 50,000 protestors attempted to block its route. The waste had earlier been sent from a German nuclear power station to an Areva processing plant in France and was being returned to an interim storage facility back in Germany.

This was not the first time Areva had faced obstruction to one of its shipments. As a market leader in commercial reprocessing of nuclear waste, the company's clients include nuclear plants in Germany, Russia and Japan. Nuclear waste is constantly moving back and forth between France and these nations – and is always accompanied by fierce protests.

According to a source close to the Gansu project, Areva made clear early in the partnership that it wanted the facility to be a processing centre for the whole of Asia. China is said to have backed this ambition. Professor Li Ning, head of the Energy Institute at Xiamen University, in south-east China, said: "In 2009, the Chinese nuclear-power sector witnessed South Korea's success in exporting nuclear plants to the United Arab Emirates and became keen to do the same – to sell nuclear services to other nations."

This means that the nuclear waste arriving in Gansu would not just come from within China, but is also very likely to be imported from neighbouring countries. However, some experts are concerned that the reprocessing technology might not yet be mature enough to deal with it.

Shao Mingchang, head of the nuclear fuel office at China's Ministry of Environmental Protection (MEP), explained that the complex chemical processes involved in reprocessing raise certain safety issues. Reprocessing of spent fuel is also extremely expensive, and there are very high demands for working procedures, equipment and material.

On January 3 this year, an official announcement trumpeted a "breakthrough" in China's nuclear fuel reprocessing technology, claiming it would "boost the utilisation rate of uranium 60-fold".

A source close to the project explained the news: "It was actually a very strong signal to the French – if you don't work with us, we can do it ourselves." China and France are engaged in a tug-of-war over the nature and ratio of investment in the 200 billion yuan (US$30.4 billion) project. "Areva is short on contracts at the moment, and its processing facilities have spare capacity," added Tsinghua University researcher Chen Jing.

Since losing out to Korea in the US$20 billion (131 billion yuan) project to build four nuclear plants in the United Arab Emirates, Areva's dominant position in the global nuclear sector has come under question. Meanwhile, the much-delayed opening of a nuclear reprocessing plant being built by a French-Japanese consortium at Rokkasho in north-eastern Japan, has been further postponed due to technical complications. (Japan's earthquake is also reported to have caused problems at the plant, which is situated in the affected Tohoku region. A spent-fuel pool reportedly spilled over and power at the plant was lost.)

Obviously, for Areva, a major contract with China will help to plug the gap.

But dialogue between the two parties behind the Gansu project has soured over price. "Even if the cost came down to 100 billion yuan (US$15.2 billion), it would still be pricey for current French technology and equipment," said Chen.

Despite this, and amid the wider controversy over nuclear waste, the project appears to be forging ahead – largely thanks to the support of CNNC, which controls every aspect of China's nuclear sector. Professor Qian Jihui, honorary president of the Nuclear Power Institute of China and former deputy director general for technical cooperation at the International Atomic Energy Agency (IAEA), admitted: "CNNC gets a big order, paid for by the government, and boosts the reprocessing industry – it's a very good deal for them."

Can it wait?

The "urgent" need to deal with China's lack of fuel-reprocessing technology was first raised in 2004. Gu Zhongmao, deputy chair of the technology committee at the China Institute of Atomic Energy,

wrote to top politicians saying that China's reprocessing technology "is two decades behind even India". Gu's remarks prompted national leaders to make public statements on the issue, though no action was taken.

According to an informed source, January's reprocessing breakthrough was made at a research project run by a CNNC factory that has been operating for 24 years on total funding of less than 2 billion yuan (US$304 million). Many experts argue that there is no need to rush into commercial projects in a field where research takes so long.

Moreover, they say, recycling fuel only becomes commercially viable when the uranium price is high. At the moment uranium reclaimed from reprocessing is much more expensive than new material. "There is a precondition for starting reprocessing projects – a shortage of uranium," said Qian.

Shao Mingchang, of the MEP, explained that, since natural uranium is the cheaper option, application of nuclear-fuel reprocessing is not yet widespread globally. Only when reprocessed fuel is used in fourth generation reactors (currently theoretical designs not expected to be ready for commercial deployment before 2030) will the economics improve, he said. And, when China's existing nuclear-power stations were designed, plenty of storage for nuclear waste was included.

"Reprocessing the waste isn't actually that urgent," said Fu Xiangang, head of the China Nuclear Power Technology Research Institute.

In the last century, France, Britain and Russia opted to recover and reuse spent fuel, but other nations are taking a wait-and-see approach on grounds of economics, safety and technological maturity. This does not mean that research into the technology has halted. For example, the US Department of Energy has continued developing and improving reprocessing technology, with government support.

And one expert who participated in China's "breakthrough" research project is confident about the future of reprocessing in his own country: "Cooperation with France would be long-term – building the reprocessing plant would take until 2020. But judging by our current level of technology, it's very likely we could build our own plant by 2025."

An earlier version of this article appeared in Southern Weekend. *It was adapted by the authors for publication on* chinadialogue.

Yuan Ying is a reporter at Southern Weekend *and Wang Haotong an intern.*

March 22, 2011

At fault on the Nu River

As China gears up for a hydropower push in its earthquake-prone south-west, it should pause to consider events in Japan, two geologists tell ***Liu Jianqiang*** *on World Water Day.*


Image from Chen Zhao

With the ongoing crisis at its earthquake-damaged Fukushima nuclear plant, Japan is paying a heavy price for ignoring "large-scale environmental evaluations". This is the assessment of two prominent Chinese geologists, Xu Daoyi and Sun Wenpeng, who told *chinadialogue* that the incident holds important lessons for China.

The two experts argue that the Japanese authorities underestimated the potential impact of deep-ocean faults and earthquakes on power plants. As a result, they failed to locate their atomic energy facilities on the country's less vulnerable west coast and, ultimately, to avoid the radiation crisis the world has watched unfold over the past week.

There are worrying parallels in China, said Xu and Sun. But rather than focusing on the nuclear industry, their gripe is with their country's hydropower sector – and, more specifically, the controversial plans to build a cascade of dams on the Nu River, China's last great waterway without large-scale hydropower and the focus of an animated public campaign.

Xu, a retired researcher from the China Earthquake Administration's Institute of Geology, and Sun, a former employee of the China National Nuclear Corporation (CNNC), who was once in charge of evaluating the nation's uranium resources, have written to the Chinese premier, Wen Jiabao, setting out their concerns. In their letter, they write that the risks of building dams on the Nu – a plan that was shelved in 2004 following a public outcry, but has recently been revived – have not been fully assessed. "We are extremely troubled by this," they add.

> *You could say Japan is on the side of a knife, while the Nu River is on the blade.*

Xu spent 40 years working in the field of earthquake prediction *[Editor's note: While earthquake prediction is a controversial or even discredited field of science in many parts of the world, in China it has long been part of the national earthquake administration's programmes on quake monitoring and disaster prevention, although reports suggest it may soon be phased out.]*. Sun specialises in structural geology and, before his retirement, worked at CNNC's Beijing Research Institute of Uranium Geology. They argue that, as the Nu River lies on a structural fault at risk of earthquakes, there are enormous risks involved in building dams there – and that pressing ahead with these plans flies in the face of common sense.

When Xu and Sun first heard about proposals for large-scale hydropower development on the Nu River -- which starts high up on the Tibetan plateau and flows through south-west China and down to the Indian Ocean -- they were shocked. "Tectonic movement in [Yunnan's] Three Parallel Rivers area is stronger than anywhere else in the world– how can they build a cascade of dams here?" asked Sun.

The pair pointed to three major risks. First, tectonic activity in this region means earthquakes are both strong and frequent. Second, other geological events

such as mudslides are common. Third, tectonic movement has been strengthening: earthquakes and other disasters are becoming more frequent in the region, claim Xu and Sun, and the combination of climate extremes, tectonic and seismic activity is increasing the risks of a major disaster.

Debate over dams on the Nu River has been raging for eight years. The first report on hydropower development on its lower and middle-reaches recommended building a cascade of 13 dams, with generating capacity of 21.32 gigawatts. But in 2004, following a public outcry, Beijing imposed a dam-building moratorium on the river. Then, in January this year, Shi Lishan, deputy head of the New Energy and Renewable Energy Division of China's National Energy Administration, said: "My belief is that development [on the Nu] is a must."

This was the first time the National Energy Administration had made clear its views, and appeared to indicate that hydropower in China is about to enjoy a "great leap forward". However, the official pronouncement has drawn fierce criticism from Chinese NGOs, the media and the public. [See chinadialogue article "Hydropower's Green Excuse" for more detail on this].

However, Xu and Sun's statements mark the first time in eight years that geologists have publicly expressed doubts over the plans. In their letter to Wen Jiabao – a geologist himself, who like them graduated from the China University of Geosciences -- Xu and Sun write: "No fixed steel and concrete dam can withstand the shearing movement of the Nu River fault, nor can anyone prevent the huge mountainside collapses, landslides and mudslides that still happen on the banks of the river."

Sun and Xu say that there is no precedent for building such a large hydropower scheme over an active fault, and that we should not be lured into complacency by China's recent successes in the construction of large dams. The unusual geology of the Nu River means that the risks here are greater than elsewhere: the fault that forms the Nu River is still active. And, if built, the cascade of dams will run directly across it. "It's like building on the blade of a knife – we are taking a huge risk," said Sun.

Even the geologists who drew up the plans for the Nu River dams agree, according to Xu and Sun. Everyone admits that the geological structure of the lower and middle-reaches of the Nu River is complex. The Nu River fault is the major geological feature of this stretch of the river and is the central factor in determining dam location and safety. "But we feel the planners weren't wary enough of those geological hazards, with risk evaluations mainly, or even only, looking at the factors affecting individual dams – these were separate 'micro-evaluations' [and not, broader 'macro-evaluations']," said Xu.

Xu said that over the past two centuries, and particularly in the last 60 years, western China (and especially the south-west) has been hit by frequent earthquakes: in 1950, an 8.6-magnitude earthquake in eastern Tibet, near the Nu River; in 1976, an 7.3-magnitude quake in Longling, Yunnan; in 1988, earthquakes measuring 7.4 and 7.2 on the Nancang River and at Gengma; in 1995, an 7.3-magnitude quake on the China-Myanmar border; and in 1996 one measuring 7.0 in Lijiang. All of these are on or near the Nu River.

According to Xu, there has been a clear increase in the number of strong earthquakes in the south-west of China over the last century, a fact that should not be ignored when evaluating regional geological stability and earthquake trends. To date, he has not encountered any geologist or seismologist who does not expect a major earthquake on the Nu River during the twenty-first century.

Both Sun and Xu believe that earthquake damage is not limited to the epicentre: its extent is related to the strength of the quake, and the stability and integrity of the surrounding geology. Even a large earthquake far away from the Nu River could trigger local disasters, such as mountainside collapses, landslides and mudslides.

Xu said that one possible scenario is that a failure at one dam causes a chain reaction in dams further downstream. If one hydropower plant is damaged, particularly if it is located upstream, hundreds of millions of cubic metres of water, carrying large quantities of mud and rock, would rush down the straight, narrow and steep river valley. The damage would be devastating. "There wouldn't even be any survivors to rescue," said Sun. "And it's an international river – if the disaster were to extend to countries downstream, I'm afraid China could not cover the costs."

Another risk is that hillsides could collapse into the reservoirs, creating huge waves that threaten the dam, or forming blockages that will impact on local hydrology and on the lower reaches of the river. The huge mudslide that hit Zhouqu in Gansu, north-west China, last year – and which many have blamed on human development in the area – should be an important lesson for those considering hydropower construction on the Nu River.

Perhaps in response to the concerns raised by these two geologists, two long-standing supporters of the Nu River plans – the China Society for Hydropower Engineering and the Chinese National Committee on Large Dams – held a meeting in Beijing on March 6, to which they invited hydropower and geological experts. Speaking at the event, Xu Xiwei, head of the China Earthquake Administration's Institute of Geology, said: "Japan lies where the Pacific plate pushes west – why can they build dams there, but we can't do the same here?"

But Sun told *chinadialogue*: "He's mixing things up. You can't compare Japan and the Nu River." Japan lies on one side of a fault, while the Nu River runs through the fault itself, he explained. "You could say Japan is on the side of a knife, while the Nu River is on the blade."

In fact, recent events in Japan demonstrate just how serious the issue is for China, added Sun. The Fukushima nuclear plant wasn't built on the fault: the problems were caused by a chain of events triggered by the tsunami. If anything happened to a dam on the Nu River the consequences could be even worse.

"Japan took a gamble by building the plant there, and lost. The officials all say the disaster could not have been predicted. In fact, the authorities were warned about the risk – and they chose to go ahead anyway."

Liu Jianqiang is the Beijing-based deputy editor of chinadialogue.

March 23, 2011

History's harsh lesson

As America mulls an atomic revival, it should look not just to Japan, but also its own past. California's radiation leak of 1959 – and the decades of friction that followed – still offer powerful lessons, writes ***Joan Bien.***

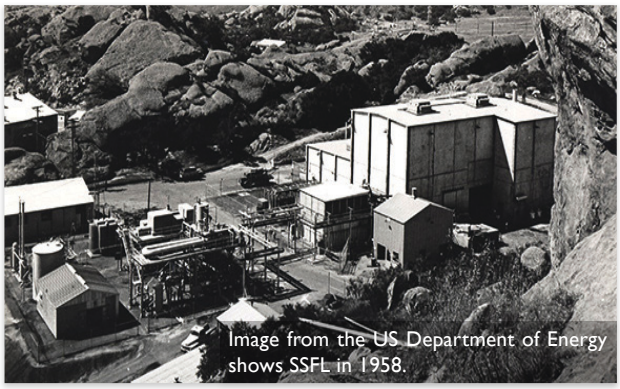

Image from the US Department of Energy shows SSFL in 1958.

On the first night of the 1959 nuclear reactor meltdown at Santa Susana Field Laboratory (SSFL) in California, John Pace was a new trainee. He arrived at the facility – a federal defence contractor compound located in hills some 50 kilometres from downtown Los Angeles – just after radiation had been vented from an overheating reactor to prevent it from exploding. "After leaking the gases, they discovered that the winds were headed toward the San Fernando Valley," said Pace. "All of our families lived [there] and all that radiation went over their homes."

Faced with massive radioactive contamination, the operators used crude methods to clean it up. "We scrubbed it down with water and sponges. We tried mops," recalled Pace, the last surviving witness from that night. "They'd get contaminated real quick and that was getting pretty expensive, so we ended up using [sanitary napkins]." In the end, the crisis went on for two weeks: each time the reactor – a sodium reactor experiment (SRE) – cooled down, the operators started it up again and, again, it overheated. Highly radioactive gases that had built up due to the extreme heat had to be released to prevent the reactor from exploding and were secretly vented each night.

So much radiation was eventually emitted that this still has the distinction of being the worst nuclear accident in the country's history. In 2006, a study by the University of California, Los Angeles, estimated that the reactor released 260 to 459 times as much radiation into the environment as the Three Mile Island accident in the state of Pennsylvania, levels

> *People today are not remembering what happened the last time we went deeply into nuclear power. We had meltdowns and accidents that now we are spending billions of dollars unsuccessfully trying to clean up.*

the authors said could translate to between 300 and 1,800 cancer deaths.

Half a century later, the story still goes on. A basic agreement was signed in December to clean up SSFL, which over the years has housed 10 nuclear reactors, a plutonium fuel fabrication facility and a lab for cutting up irradiated nuclear fuel from around the country, plus rocket-testing and munitions-development facilities. But the parties with responsibility for the site – NASA, California, the Department of Energy and Boeing – are still wrangling over the details of the cleanup and are embroiled in two court cases. As the US decides whether or not to embark on a nuclear revival, many argue this incident and its aftermath offer a warning from history.

Dan Hirsch, president of non-profit organisation Committee to Bridge the Gap – an anti-nuclear lobby group that has been battling to get the SSFL compound cleaned up for more than 30 years – is one such voice. "People today are not remembering what happened the last time we went deeply into nuclear power," he said. "We had meltdowns and horrible accidents that

now we are spending billions of dollars unsuccessfully trying to clean up."

Even now, the US Department of Energy (DOE) is still unsure of the full facts surrounding the 1959 reactor meltdown. DOE spokesman Bill Taylor told chinadialogue: "We know there was the fuel meltdown. We don't know how much or if any was released. [We] don't know exactly what happened 50 years ago."

At first, the public was not even told that anything had happened. Then, five weeks after the incident, a news release was issued saying that there had been an event, but that no danger had been posed to the public. The truth partly came out 20 years later, when a University of California Los Angeles (UCLA) researcher accidentally came upon archive material. And then, in 2009, Pace came forward to give his version of events, out of concern that the facts were being concealed.

Local people may not have been informed about developments, but they were affected. Bonnie Klea, now 68, contracted bladder cancer after working at SSFL for eight years and living close to the facility for decades. She has been proactive in convincing the federal government to expand its worker compensation programme. Klea told *chinadialogue* that, until recently, the government programme to compensate federal energy workers was based on readings from radiation badges. However, at SSFL, the badges were collected by the facility and have now gone missing. Klea filed a petition to compensate more SSFL workers, which was approved in 2009.

Radiation impacts are not the only concern. Hirsch's campaign has also focused on the cleanup of dangerous chemicals that were regularly used in unsafe practices at the site. The carcinogen trichloroethylene (TCE), for example, was used to wash down stands used for rocket tests, subsequently making its way into the surrounding environment, said Hirsch: "Half a million gallons of TCE are estimated to have migrated into the groundwater and deep soil." He continued: "Groundwater was badly contaminated, and only belatedly stopped being used for drinking water onsite."

Hirsch added that contaminated process water was used for irrigation and cleaning throughout the site, spreading the pollution and sending plumes of toxic steam into the air and the neighbouring communities.

A programme to pump and treat the tainted area began in the 1980s, explained Hirsch, but only removed 10 gallons of TCE a year: "At that rate, it would take 50,000 years of pumping to remove the TCE – except the pumping has been shut down since 2000." Meanwhile, a quarter of the water wells in Simi Valley, which has a population of more than 100,000, have been found to be contaminated with perchlorate, a chemical that disrupts iodine uptake.

In 2008, Hirsch testified before a United States senate hearing on cleanup efforts at public facilities. He explained that illegal practices had continued at SSFL up to the mid-1990s when, long after open-air burning of hazardous materials was supposed to have stopped at the site, an explosion killed two workers. The FBI raided the facility and the US Attorney issued felony charges. The operators eventually pleaded guilty to three environmental felonies and received a US$6.5 million fine (42.9 million yuan).

After more than 50 years of radioactive, chemical, and toxic heavy-metal contamination, a basic clean-up deal was signed on December 6 last year. The agreement between the state of California, NASA (which owns a stake in the site) and the US Department of Energy (DOE) guarantees that the much-delayed remediation of the highly contaminated site will be carried out to the strictest standard – that of agricultural land. The programme is expected to complete by 2017.

The primary purpose of the agreement is to provide a blueprint for the NASA and DOE clean-up efforts. It was prompted by decades of disagreements between the various stakeholders of the compound and the state regarding the acceptable final standard of the cleanup.

US aerospace and defence corporation Boeing, which owns the majority of the 2,800-acre property, did not sign the agreement. The firm had previously agreed to pay US$22.5 million (148.4 million yuan) to the state each year for 30 years for site maintenance and committed to restore the land to residential standards – a less stringent requirement than set out by the new deal. Boeing filed a lawsuit in federal court against California in November 2009, claiming that only the federal government has jurisdiction to regulate the site. The case is expected to continue into 2011. Boeing also stated that it is suing to reserve its legal rights to challenge the cleanup standard set by the state. The case is expected to go to court this summer.

As the squabbling continues, Hirsch hopes that the lessons from the 1959 environmental disaster – and other practices as SSFL – will not be ignored. The contaminated site still poses a serious pollution threat to the air, land and water supplies in an area populated by half a million people.

"Who would have thought," asks Hirsch, "that in the midst of the Cold War, the only American victims of radiation would be caused by our own government?"

Joan Bien is a freelance journalist based in California.

March 25, 2011

The view from Jaitapur

The crisis in Japan has brought fresh scrutiny to plans for the world's largest nuclear plant on the west coast of India. ***Joydeep Gupta*** *reports.*

The radiation leak from Japan's Fukushima nuclear-power plant, triggered by the powerful earthquake and tsunami on March 11, has raised fresh questions about plans for the world's largest nuclear-power station on the west coast of India. After months spent riding roughshod over protesters fighting the project in the state of Maharashtra, the Indian government has adopted a slightly different tune. The authorities say they will review and enhance safety features at the proposed plant, though they still insist "there is no alternative to nuclear power".

Residents of Jaitapur – the mega-plant's proposed home, south of Mumbai – are unimpressed by the government's arguments. "Do they take us to be fools?" asks Milind Desai, a doctor who practises in the nearby town of Mithgavane. "NPCIL [Nuclear Power Corporation of India Limited] officials earlier tried to tell us that radiation is harmless because there is background radiation in nature. Now after the disaster in Japan, they suddenly tell us they'll put in extra safety precautions. Why should we trust them?"

The mistrust is increased by the opacity of India's nuclear establishment. The government's Department of Atomic Energy (DAE) owns NPCIL and also runs the Atomic Energy Regulatory Board (AERB), where any citizen wishing to make a complaint about the nuclear industry must go. People cannot even use the Right to Information law to find out what is going on, as anything nuclear falls under the Official Secrets Act, making it exempt from transparency regulations.

Jaitapur's residents have protested for five years against the proposed complex of six reactors, each capable of generating 1,650 megawatts of power.

Image from Greenpeace shows a protest at Jaitapur.

> *Environment minister Jairam Ramesh has said his department is now likely to ask for additional safeguards before clearing the project.*

The government has responded by jailing protestors and banning civil-society activists from entering the area – that was until the Fukushima incident showed the world that even safety-conscious Japan can fail to avert a serious nuclear accident.

NPCIL chief SK Jain has said that the reactors being designed for Jaitapur by French firm Areva are different from those at Fukushima – and therefore safer. But now even the AERB's former head A Gopalakrishnan is asking why the residents of Jaitapur should be made guinea pigs for a new design. The model in question – the Evolutionary Power Reactor (also known as the European Pressurised Water Reactor) – is not yet up and running anywhere in the world. The first one is being built in Finland, where it has run into many problems (construction is running at least four years behind schedule and 2.75 billion euros over budget).

A long-time critic of India's nuclear policy, journalist and activist Praful Bidwai, said: "The EPR is the largest-ever nuclear reactor designed in the world and has a much higher density of fission-causing neutrons and fuel burn-up than do normal reactors [of 500 megawatt to 1,000 megawatt capacity]. The EPR's high fuel-combustion rate will lead to greater production of harmful radionuclides, including seven times higher production than normal of iodine-129, with dangerous

implications for radioactivity releases, damage to the fuel cladding and waste generation."

In the wake of the Fukushima disaster, Indian prime minister Manmohan Singh announced in parliament that safety issues at all nuclear plants would be re-examined, while environment minister Jairam Ramesh has said his department is now likely to ask for additional safeguards before clearing the Jaitapur project. But Gopalakrishnan remains scathing about the way safety issues are tackled in India.

"In India, we are most disorganised and unprepared for the handling of emergencies of any kind of even much less severity [than the earthquake and tsunami in Japan]," Gopalakrishnan wrote in the Daily News and Analysis on March 18. "The AERB's disaster-preparedness oversight is mostly on paper and the drills they once in a while conduct are half-hearted efforts which amount more to a sham.

"In case of earthquake engineering, the Nuclear Power Corporation strategy is to have their favourite consultants cook up the kind of seismic data which suits them, and there is practically no independent verification of their data or design methodologies. A captive AERB, which reports to the DAE, makes the overall nuclear safety management in India worthless."

NPCIL officials have been quick to point out that Jaitapur is in seismic zone three – moderate risk – while Fukushima is in high-risk seismic zone five. But both are on the coast and face the same tsunami threat. Most nuclear power plants are located by the sea because they need huge amounts of water to cool the reactors. This is a strategy that may have to be reviewed in light of the two large tsunamis that have taken place within the last seven years. The last one, in 2004, dumped debris into underground tanks being built for nuclear-waste storage at the Kudankulam nuclear-power plant on India's south-eastern coast. It took NPCIL two years to remove the debris. If the plant had been in operation, there would have been no place to store radioactive nuclear waste.

The Jaitapur project has raised a host of concerns, beyond the radioactive risk. One is that project developers have deliberately played down the value of the land in order to minimise the compensation they must pay. NPCIL stated in its project report that two-thirds of the area where it would set up the nuclear complex was "barren". In fact, it is not only part of the lush-green coastal belt, but also home to the world's costliest mango, the Alphonso. Each mango sells for around US$2.50, even in the domestic market and some of the orchard owners are very wealthy. Little wonder 95% of the people asked to vacate their lands to make way for the project have refused to do so.

The fishing beds in the Arabian Sea are also very rich, and much of the catch is exported to Japan and the European Union. But this industry is threatened by the nuclear scheme – the fish are not likely to stay near a spot where a plant discharges water into the sea five degrees hotter than the ambient temperature. Even if they do, EU rules demand that the temperature at which fish are caught is specified, and so the consignments will be rejected. Overall, as the respected Bombay Natural History Society pointed out in a recent report, without a comprehensive biodiversity assessment – which has not been done –"the true impact of a project of this scale will never be known".

News that one of the project's main funders, Germany's second-largest bank Commerzbank, has pulled out (according to information obtained by the India office of the environmental NGO Greenpeace) comes as little surprise. Civil society activists say that, unless the government puts pressure on one of the insurance firms it owns, no one will be willing to insure the project either. Against a background of growing unease over nuclear development around the world, India's ambitious programme may too be starting to unravel.

Joydeep Gupta is project director (south Asia) of chinadialogue's *third pole project.*

March 29, 2011

Why greens should support nuclear

Mark Lynas is an author, environmental activist and fierce proponent of nuclear power. Here, he tells ***Olivia Boyd*** *why, even after Fukushima, his faith in the merits of atomic energy is firm.*

Image from Channel 4

Olivia Boyd: The Fukushima crisis in Japan has reignited a debate over the merits of nuclear power. Is it a useful conversation?

Mark Lynas: Oddly enough, one of the effects of debating for and against nuclear power is to sideline the climate-change deniers, because it's an accepted truth by both sides that global warming is real and urgently needs to be dealt with. That's one possible good side to this whole thing.

With regard to the pros and cons of nuclear itself, again it may be good to get the debate properly out into the open, particularly about the safety aspects, because that's what most preoccupies the general public. Explosions, repeats of Chernobyl, radiation, dangers of cancer – that kind of thing is central to the public perception of nuclear. So what's happening at Fukushima I think will ironically illustrate how many of the public fears about radioactivity are vastly overblown.

OB: That doesn't seem to have been the reaction to previous nuclear accidents though.

ML: Well, it's difficult to say that. Take Three Mile Island for example, it's mentioned a lot in the discussion and pretty much everyone has to admit that nobody was hurt, still less was anyone killed as a result. So, scary as it might have been at the time, it really was a very minor industrial accident, especially when set against the dangers of pretty much any other large-scale source of energy.

> *"The Chinese nuclear programme was the best news for global warming in a decade…in decades to come, the emissions reductions would be measured in the many billions of tonnes of carbon dioxide."*

Again, Chernobyl of course represents a real world example of pretty much the worst case scenario of a nuclear disaster. And, again, there's been a long-term collaborative scientific effort to study the impacts of that and they're much, much less than originally feared. In fact, I think the most scientifically valid conclusion has been that the fear of radiation has been much more damaging than the radiation itself to the population.

OB: Radiation fears in China have prompted panic in recent weeks, for example stock-piling of salt. At the same time, the government has announced suspension of approvals of new nuclear plants while it reviews safety rules. What's your reaction?

ML: Well, the Chinese nuclear programme was the best news for global warming in a decade. Every nuclear plant is very likely to substitute directly for a coal plant, which isn't necessarily the case in other countries. So the emissions reductions are enormous and, in decades to come, would be measured in the many billions of tonnes of carbon dioxide.

The reaction of the Chinese government, I'm certain, will have been a response to the public fears, which have been wildly disproportionate to any danger

from Fukushima. But we have to deal with – and the Chinese government has to deal with – the public as it is, not as you would wish them to be. And it may well be, then, that the nuclear programme is set back or curtailed. I certainly hope not.

OB: Even taking into account all of China's nuclear construction plans, we're still only talking about something like 4% to 6% of energy supply by 2020. Is that really world-changing stuff?

ML: I think it is significant. In terms of single slices, or wedges of the problem, it's a big one, because Chinese coal is probably the biggest single energy-source contributor to climate change.

It's particularly significant given that what matters to the climate is cumulative emissions. So, when you're assessing our chances of staying below two degrees Celsius, for example, [keeping warming below two degrees Celsius above pre-industrial temperatures is the climate-change goal recognised by the Copenhagen Accord] you have to look at emissions right out to 2050 and, by that time, China could be substantially nuclear-powered. And we'll be looking at a world that's much more electrified too, in terms of transport and probably heating as well, certainly for industrial economies. So the proportion of energy which is used and delivered in electricity will be going up and, hopefully, the proportion of electricity which is generated through low-carbon renewables and nuclear will be going up at the same time.

OB:You're pretty dismissive of public fears about nuclear. But looking at the news – the tap-water problems in Tokyo, contamination of the food supply – is it not legitimate for people to feel concern?

ML: The problem with the stories about radiation is that people have no way of properly assessing risk. It remains a truism that the risk from air pollution is enormously greater than any statistically insignificant risk from radiation. But the media picks up on increased radioactivity because it can be measured extremely accurately. The publicly acceptable levels of things like radioactive iodine in tap water are set well, well below what is likely to be harmful to public health for good, precautionary reason. But the fact that a minute quantity of the stuff is there doesn't mean that it's actually likely to be harmful to anyone.

Within the context of the natural disaster that has killed 10,000 or 15,000 people, I really think that we're talking about the wrong thing here. The tsunami wave which washed over fertile fields as well as towns, will have carried enormous amounts of toxins and car batteries and petrol tanks, goodness knows what else. That's a much, much greater contamination problem I would have thought than the tiny levels of radioactivity emitted from Fukushima.

OB: So why are people focusing on the nuclear aspect so intently?

ML: This is a 50-year cultural issue, the public excitement and concern about all things nuclear, and it's completely contradictory – people happily accept large doses of radiation for medical purposes, but are extremely paranoid about minute doses received from nuclear-power stations. And I don't think there's much understanding either about the extent to which natural background radiation is ubiquitous in the environment and in our own bodies.

People don't have any context for this discussion: radiation is scary, it causes cancer, pictures of people with hair falling out, mental images of atomic bombs – case closed. We know that people in general don't assess risk rationally. You can tell this from all sorts of lifestyle behaviour patterns, but it is particularly the case for nuclear power.

OB: Nonetheless, are there lessons to be taken from Fukushima, in terms of planning policy for example? Should we stop building nuclear plants in earthquake zones?

ML: Any kind of infrastructure in extremely seismic areas has to be properly thought through – that goes for tall buildings, hydroelectric dams, which could

breach and cause inland tsunamis, a whole host of other things. Nuclear-power stations are included of course.

But remember, it was the tsunami that did the damage here. And the plants were properly and automatically shut down during the earthquake, which after all was much stronger than they were designed for. And I think we should also be cautious about judging newer designs on the basis of 1960s technology. The same applies to aircraft: we don't worry about travelling on a new Dreamliner because there was a plane crash in 1970.

OB: In your book Six Degrees, you paint a bleak vision of a world changed by runaway climate change. What about if we're talking about nuclear plants in that kind of world? Is there increased risk?

ML: I don't really think so. I mean, there's a potential increased level of danger because of higher storm surges, and given most nuclear infrastructure is located on the coast for reasons of access to emergency cooling – as was needed at Fukushima. But I don't think this is a very viable large-scale argument against nuclear power.

It's an engineering challenge, and anyone looking at Fukushima will see that the real problem was that the single disaster of earthquake and tsunami overwhelmed the back-up system and the back-up, back-up system at the same time. And you need to design your back-up systems so that they're independent of each other. Certainly, there are engineering lessons to be learned, but I don't think they in any way undermine the need for increased nuclear power more generally.

OB: What about rising sea levels?

ML: If you're talking about plants with lifetimes of 40, 50, 60 years at the most, I don't think even rising sea levels are a significant concern. At the very most, we'll see less than a metre by 2060 or so and any increased flooding from that would be containable.

And remember, this idea that the ground under a nuclear reactor is contaminated forever and needs to be isolated from the sea is another erroneous one. These plants can be properly decommissioned and radioactive materials moved offsite and levels of lingering contamination are then virtually un-measureable.

This is a fairly standard anti-nuclear talking point, but isn't one which, even for someone writing about global warming, is particularly valid.

OB: Another talking point is the degree to which nuclear actually is a low-carbon source, when you take into account the full cycle including uranium-mining and plant construction.

ML: Nuclear is more low-carbon than solar photovoltaics and about equivalent with wind. And there have been umpteen studies concerning this, including from the IPCC [Intergovernmental Panel on Climate Change]. That talking point is again little more than an urban myth. Of course nuclear is low-carbon, simply by dint of the technology it's using and the energy source it's based on.

Every wind turbine is made of steel and placed on a concrete platform. It takes a lot of energy to make solar panels. There's a lot of concrete and steel going into a nuclear reactor and a fair amount of mining effort, although fourth-generation nuclear [theoretical reactor designs currently being researched] would mean we could actually use a lot of the stuff that's already out there in stockpiles. But nuclear fission is so concentrated as a source of energy – it delivers a million times more volumetrically than coal. It's blindingly obvious that nuclear is going to be extremely low carbon and potentially made zero carbon in decades to come.

OB: You are a strong advocate of nuclear power now, but that wasn't always the case. What made you change your mind and do you think it's an argument you can win?

ML: I didn't want to be a green arguing against any low-carbon technology. That struck me as irrational, potentially counter-productive. Writing a book about just how terrifying escalating global-warming impacts could be made me realise that, proportionally, nuclear power was utterly safe and something I was prepared to be very comfortable with. More recent work I've done suggests it's more ecologically friendly in terms of land use and water use and other things that ultimately matter to the biosphere than many other power sources that greens do support.

Ultimately, it was a case of trying to reconcile my views and ideology with the scientific evidence and I realised that, if I was to apply the same standard for nuclear as I do for climate change, then I had to alter my position. Those in the green movement who haven't done so, I see them as being just as anti-science as the climate-change sceptics are, in a different field. There isn't the evidence out there to support their viewpoint, so their viewpoint needs to change.

Olivia Boyd is assistant editor at chinadialogue.

April 6, 2011

In Shanxi, lasting pain (1)

A fatal radiation incident 19 years ago still casts a shadow over the lives of a mother and daughter in north China, reports ***Cui Zheng*** *in the first instalment of a two-part article.*

Image from Biaidu Baike

> *The first time the local authorities were contacted about the case of radiation sickness, they even denied it had happened.*

Zhang Jingsheng puts on some light make-up, ties her hair back in a ponytail and leaves the house in a short jacket, grey wool dress, glossy tights and heeled boots. Heads turn as this beautiful young woman, who turned 18 in March this year, walks down the bustling streets of Xinzhou in Shanxi province.

Nobody would guess that her mother was exposed to radiation when she was 19 weeks pregnant. This was China's first confirmed case of in-utero irradiation, and the Zhang family's story is on record at the International Atomic Energy Agency.

At home, Zhang Jingsheng is Jingjing, much-loved daughter of her mother and step-father. In neighbourhood gossip, she's Jingsheng, whose father tragically died before she was born. And in research papers, she is the subject codenamed "Jing", who grew up to have an IQ of only 46.

Zhang Jingsheng's family live in Xinzhou's Nanguan village, a 10-minute walk south of the landmark Jinbei gate, where the old city used to be. But the city has developed towards the north, leaving Nanguan behind. "This is a slum now," says Jingsheng's mother Zhang Fang.

Zhang Fang, 42, has dark and shiny curly hair, but if she lowers her head, shocking white roots are visible. "It's dyed. My hair turned white when I was 30," she says quietly. "If none of it had happened, things would be so much better now."

The Zhang family will never forget November 19, 1992. That day, Zhang Youchang, a builder, went out to work as usual. His new wife, 23-year-old Zhang Fang, was working as a loom operator at a local textile factory.

"He was back before noon," Zhang Fang's father, Zhang Chouyin, recalls. "He said he felt sick, his stomach hurt, he couldn't stop vomiting."

The doctors at Xinzhou Hospital couldn't work out what was wrong, so Zhang Chouyin took his daughter – pregnant at the time – home to rest, while Zhang Youchang's brother Zhang Youshuang stayed at the hospital. But four days later, Zhang Youshang also fell ill, his cheeks and saliva glands turning a frightening shade of purple. The hospital panicked and isolated them both on an infectious diseases ward.

A week later, Zhang Chouyin, together with Zhang Youchang's father Zhang Mingliang carried the brothers to the hospital at Shanxi Medical College in Taiyuan. Zhang Youchang was losing his hair, and his right thigh and the right side of his stomach were turning purple. For the first time, Zhang Chouyin heard the phrase that would haunt him for the rest of his life: "radiation sickness". After consultation, the doctors raised this

as a possibility – but the provincial health authorities dismissed the idea, as there was no record of any radiation incident in Xinzhou.

Unable to get a diagnosis from the hospitals in Taiyuan, the two brothers were taken home. On December 3, after 14 days of suffering, Zhang Youchang died. The next day, Zhang Youshuang lost a clump of hair while washing, later he found blood in his stool and developed a fever. Three days later, he also died.

Then Zhang Mingliang fell ill. And, after two days, his breathing difficulties became so severe that he too passed away.

Nineteen years later, Zhang Chouyin still chokes up when he talks about the loss of his daughter's family. He says that, only a few days after Zhang Mingliang died, Zhang Fang started to lose her hair. At the hospital, tests revealed that her white blood cell count was low. That night, Zhang Chouyin took his daughter on the train to Beijing.

The day after they left, the local epidemic-prevention station announced that everyone who had had contact with the family was to be isolated. "If we had left it one more day, we wouldn't have been able to leave," says Zhang Chouyin. "When we got to Beijing, my daughter was already too weak to move."

After being passed between several hospitals, Zhang Chouyin and his daughter arrived at Beijing People's Hospital (now Peking University People's Hospital), known for treating diseases of the blood. By this point, Zhang Fang's white blood cell count was less than one tenth of normal levels.

Zhang Chouyin is still grateful to professor Lou Bincheng, director of the hospital's emergency room. "They wanted a 40,000-yuan [US$6,100] deposit – for a rural family that's an astronomical sum. I'd already bought tickets home, but professor Lou stopped us and said they would treat her for whatever we could afford."

"We might not have been the best hospital, but we had a conscience," says Lou, who retired in 2000. He was worried that, with such a low blood count, an infection could kill both Zhang Fang and her unborn child.

Back then, Wang Zuoyuan was head of the Industry Health Laboratory at the Ministry of Health (now the China Centre for Disease Control's National Institute for Radialogical Protection). He remembers an anxious Lou turning up to tell him about a suspected case of radiation poisoning. On December 20, they held an expert case conference and, after an analysis of lymphocyte abnormalities, a diagnosis of moderate acute bone marrow-type radiation sickness due to exposure to cobalt-60 was made on December 30.

Radiation sickness is usually caused by the body absorbing over 1 gray of radiation (the gray is the scientific unit of absorbed radiation dose), while bone marrow-type radiation sickness is characterised by damage to blood function. In a paper published later by Lou and colleagues, they estimated that Zhang Fang had absorbed a radiation dose of 2.3 grays.

Wang Zuoyuan is retired now, but at the time of the incident he was head of the Institute for Radiation Protection. He flips through a thick folder full of material relating to the radiation incident at Xinzhou and recalls the struggle to find the cobalt-60 radiation source. "It was stranger than a TV detective show," he says.

In 1973, Xinzhou's Science Committee obtained six cobalt-60 radiation sources to improve crop quality (in a process called food irradiation, crops are exposed to ionising radiation to destroy bacteria, viruses and so on). When the committee moved over a decade later, the sources were sealed in a vault and the building handed over to the local environmental-monitoring station.

In 1991, the station asked the Taiyuan-based China Institute for Radiation Protection to remove and store the cobalt-60 radiation sources. But the number of

sources in the underground vault had been incorrectly recorded, and only five of the six metal cylinders were removed. Nobody asked where the sixth was.

On November 19, 1992, builder Zhang Youchang arrived at Xinzhou's environmental monitoring station – his team was to dismantle the 1-metre wide, 10-metre deep vault. By the entrance, Zhang Youchang saw a metallic cylinder sparkling in the sun. He picked it up and popped it into his pocket.

It was the radiation from that piece of metal that killed him, his brother and his father, that harmed Zhang Fang and her unborn child and that eventually affected more than 100 people.

The Ministry of Health dispatched a team to track down the source of radiation. Someone from the hospital in Taiyuan recalled a metallic cylinder falling from Zhang Youchang's pocket while he was there. It had subsequently been thrown away and the rubbish removed by the bin men. The rubbish should have taken it to the landfill outside of town, but to save some time the bin men stopped halfway and dumped it by the road.

"We went to the landfill first – we were shocked to see this huge dump full of rubbish," says Wang Zuoyuan. How long would it take to find a radioactive needle in that haystack?

But under public security bureau questioning, the two bin men admitted that they had broken the rules. Clad in protective gear and using a construction digger, the Ministry of Health team searched for the cobalt-60.

Surprisingly, despite being under orders from their superiors to find the cobalt-60, Wang Zuoyuan and his colleagues found some of the local authorities uncooperative. The first time the Shanxi authorities were contacted about the cases of radiation sickness, they even denied it had happened.

Ten years later, Wang visited the area again, this time with a television crew filming a documentary about radiation sickness. Despite a letter of approval from the provincial communist party committee, they were turned away at the hospital and elsewhere.

This article originally appeared in Century Weekly, *where Cui Zheng is a trainee reporter.*

April 6, 2011

In Shanxi, lasting pain (2)

Across China, radiation sources are used in healthcare, agriculture and industry. But sloppy management has led to accidents, writes ***Cui Zheng****, concluding a two-part article.*

Image from caing.com shows Zhang Fang (right) with her daughter Zhang Jingsheng.

The Zhang family tragedy was the only case of radiation poisoning that Lou Bincheng dealt with in his long career as a doctor. But radiation safety specialist Wang Zuoyuan knows that, in China, incidents involving radiation exposure are not infrequent.

There are innumerable radiation sources all over China, used in healthcare, agriculture and industry. If you added up all the deaths and injuries resulting from failures in the management of these sources, they may well exceed the impacts of the Category 5 radiation leak at Japan's Fukushima nuclear-power plant.

Figures made public by China's health and public security ministries show that, between 1988 and 1998, there were 332 recorded radiation incidents in China and 966 people were exposed to radiation. 80% of these incidents involved the loss of radiation sources – 584 were lost, 256 of which were never found.

For example, the Institute of Vertebrate Paleontology and Paleoanthropology at the Chinese Academy of Sciences purchased a cesium-137 source in 1972; in 1988, it was found to be missing. On June 25, 1990, a breach of procedure in handling cobalt-60 at the radiology lab at Shanghai's Second Military Medical University killed two workers and left five with radiation sickness.

Wang Zuoyuan points out that, in the 1990s, China had almost the same number of radiation incidents as the United States, but when the number of radiation sources in each country is factored in, the rate of accidents in China is actually 40 times higher.

In 1998, regulation of radiation sources was tightened as it was passed from the Ministry of Health to the environmental authorities. But accidents still happen. On April 26, 1999, the lead container of a cobalt-60 radiation source was sold as scrap metal in Henan, resulting in the irradiation of a number of people. On October 21, 2004, equipment being used to manufacture cobalt-60 sources at a factory in Jining, Shandong, failed. Two workers entered the workshop without checking radiation levels, and died of multiple organ failure five and 10 weeks later.

> *The focus of economic development needs to shift from expansion and investment to the quality and fairness of growth, and its social and environmental impacts.*

On April 11, 2008, five workers at Shanxi Hengze Radiation Technology, wearing defective dosimeters – devices for measuring radiation levels – entered a workshop where a source of radiation had not yet been placed in a safe position. One died, the other four suffered radiation sickness.

Even today, some areas of China see numerous failings in management of radiation sources. After the accident at Fukushima, Qinghai's environmental authorities checked up on radiation sources at companies including a subsidiary of China National Petroleum Corporation in Haixizhou. There were some common safety issues, such as untrained workers and a lack of health monitoring.

The aftermath

In 2009, Zhang Fang received her last compensation payment for her husband Zhang Youchang, who had already been dead for 17 years: 60,000 yuan (US$9,200). She doesn't think the money will make any difference to her life.

Zhang Fang remarried and became pregnant twice, but neither pregnancy was carried to term. "I'm scared that if I did have another child, there would be problems," she says. Tests indicated that a miscarriage she suffered in 2000 was related to her earlier exposure to radiation.

Eighteen years ago, when she was carrying her daughter Jingsheng, Zhang Fang was unsure whether she should go ahead with the pregnancy. For a while, the foetus stopped growing and its head circumference was smaller than normal. The doctor tried to persuade Zhang to have an abortion on the grounds that exposure to radiation could have consequences for the child. But she couldn't bring herself to do it, and she wanted her husband to have left behind a child.

Jingsheng weighed just two kilograms when she was born. She had little hair and problems feeding. Zhang Fang struggled to raise a weak and sickly child singlehandedly.

When Jingsheng was eight-months old, there was still no sign of compensation from the Xinzhou Science Committee, the environmental station where the source had been found or the China Institute for Radiation Protection. With the one-year limit on bringing a court case about to expire and no money for a lawyer, Zhang Fang's father Zhang Chouyin personally sued all three.

In 1997, a verdict was finally reached and the three defendants were ordered to pay out a total of 780,000 yuan (US$119,000), of which 320,000 yuan (US$49,000) was to go to Zhang Fang and her daughter as compensation. The following year, the defendants appealed, and the amount that each had to pay was clarified, but the total figures did not change.

In the following three years, Zhang Fang was often too ill to work. She had no income at all, but still the compensation did not appear.

So Zhang Chouyin took his daughter and baby granddaughter to each organisation's offices to demand payment. They were even detained for two nights after blocking an entrance. Eventually they managed to obtain a letter from the provincial authorities requiring that payment be made but, locally, it made little difference.

In 2002, 10 years after the actual accident, the Xinzhou Science Committee finally relented, agreeing to "first pay 80% of the compensation". In the following years, Zhang Fang received a number of payments – but she still had to give out kickbacks. "There are a lot of things we just don't want to think about. In the end we got something over 200,000 yuan," (US$30,500) she says.

She was more worried about her daughter's cognitive development. Jingsheng started elementary school when she was eight and it became clear she was different from other children. Her homework wasn't good enough, particularly in maths. No matter how hard she tried, she couldn't manage to add or subtract double-digit numbers. She made it to the end of junior middle school, even though most of the time she didn't understand the lessons.

In May 2010, the National Institute for Radiation Protection and Peking University 3rd Hospital published a paper which calculated that, while in the womb, Jingsheng received a radiation dose of 1.85 grays, which did not affect her physical development but had a major impact on her cognitive development. On the Wechsler Intelligence Scale for Children, she obtained an IQ score of only 46 – lower than 99.9% of the population.

Now Jingsheng is as tall as her mother. She was once invited to work in a beauty salon a trainee, but it didn't work out. "She looks good, the other staff and customers all like her," says her mother. "But she can't sell anything – she's no good with numbers."

Zhang Chouyin has worked out that the compensation decided years ago now looks too low. "In 1992, it cost 19 yuan for a hard seat ticket to Beijing. Now it's 72 yuan. How many times has it gone up?" He was also affected by the radiation and his health is getting worse – he has lost teeth and suffers back pain.

Jingsheng is from a rural area, is not entitled to welfare payments and doesn't have a job. Looking at the hospital letter confirming her IQ, her mother worries out loud. If she registers Jingsheng as disabled, the welfare authorities might find her work. "But she's a girl and will need to get married soon. If she has a label like that, who's going to want her then?"

This article originally appeared in Century Weekly, *where Cui Zheng is a trainee reporter.*

April 25, 2011

Chernobyl – a poisoned landscape

In Ukraine, 25 years on from history's worst nuclear accident, ***Robin McKie*** *sees dramatic reminders of the reactor explosion's enduring and harrowing legacy: radioactive soil, abandoned towns and polluted lakes.*

Yuri Tatarchuk has a disconcerting way of demonstrating Chernobyl's grim radioactive legacy. An official guide at the wrecked nuclear power plant, he waves his radiation counter at a group of abandoned Soviet army vehicles that were used in the battle to clean up the contamination created by the reactor explosion in 1986.

"Some of these trucks are quite clean, but some of them not," he announces. A sweep of his counter reveals only a few clicks from their doors and roofs. Then he passes the device over one vehicle's tracks. A sudden angry chatter reveals significant levels of radiation.

"Wheels and tracks pick contamination from the soil," he tells the group that has gathered round him. "There are still plenty of radioactive isotopes – caesium, strontium, even some plutonium – in the ground and we cannot get rid of them." Twenty-five years on, Chernobyl remains a poisoned landscape.

Set among lakes, sandy soil and forests on steppe lands north of Kiev, Chernobyl achieved global notoriety in 1986 when technicians carried out an experiment aimed at testing backup electrical supplies to one of the plant's four reactors. The flow of water – used as a coolant to carry away the mighty heat of the reactor core – was raised and lowered.

Image by Gregory Kowalski shows the Chernobyl nuclear plant and an old geiger counter.

After a few minutes, there was a sudden jump in reactor power. Ten seconds later the core was blown apart by a massive explosion.

> *Kopachi was very badly contaminated and so it was decided to bury it, house by house ... The digging only pushed radioactive material deeper into the soil and closer to the water table, so that contamination spread even further.*

Without a containment vessel, the reactor's deadly radioactive contents were borne high into the air by the heat of the core's burning graphite and spread over much of Europe, triggering an international panic.

In the blast's immediate aftermath, 31 plant operators and firemen died – they were not told the reactor was the cause of the blaze or that radiation levels were lethal – while thousands more people, living on land that is now in Ukraine and Belarus, received doses that undoubtedly shortened their lives, although scientists still dispute the death toll. The World Health Organisation puts it at 4,000; Greenpeace says 200,000.

Significant levels of radioactive caesium-137, strontium-90 and plutonium isotopes still pollute the ground. In one zone, dubbed the Red Forest, it reached levels 20 times higher than the contamination at Hiroshima and Nagasaki and remains highly dangerous.

The Chernobyl explosion was the world's worst nuclear accident and until recently was the only one classified as level 7 on the International Nuclear Event Scale. April 26 will mark the 25th anniversary of the blast, a birthday that has acquired a dramatic resonance following the Fukushima reactor fires in Japan, which have resurrected global fears that nuclear mayhem could afflict the planet again. The Fukushima disaster is now also classified as level 7.

Chernobyl clearly has much to tell us about the dangers of nuclear power. Hence the recent soaring interest in the plant which, bizarrely, has become a popular tourist destination for foreign visitors to Ukraine. My coach trip in March from Kiev was a sellout – with the 25-strong party including 15 members of the German, US, Russian, Dutch and British media. Television crews fought to interview the few baffled members of the public on the bus about the forthcoming anniversary, while other journalists simply interviewed each other. I was cross-examined for Russian TV about the safety of nuclear power as I stood in front of the radioactive ruins of reactor number 4.

It was an extraordinary affair led by the ebullient Tatarchuk, a chunky, cheerful Ukrainian wearing a T-shirt bearing the slogan "Hard Rock Café – Chernobyl". Sites on our strange tour included the buried village of Kopachi, a close-up look at reactor number 4 itself, a very quick drive through the Red Forest and an exploration of the abandoned city of Pripyat. Radiation counters were handed out, and if these started to chatter too quickly – usually if we wandered off paths and on to open soil – we were told to make a detour. It was startlingly casual and, in the end, highly unsettling.

The Ukrainian steppe is still frost-burned and the trees leafless at this time of year. There are no buds on branches and little hint of greenery, a combination that only enhances the eerie desolation inside the 30-kilometre exclusion zone around the reactor. This land has seen harrowing times. It was occupied by German troops and most communities have memorials to the Soviet soldiers who liberated them – including the village of Kopachi inside the zone. In fact, Kopachi's memorial is just about all that is left of the place, thanks to Chernobyl.

"Kopachi was very badly contaminated and so it was decided to bury it, house by house," says Tatarchuk. "It seemed a good idea at the time, but it wasn't. The digging only pushed radioactive material deeper into the soil and closer to the water table, so that contamination spread even further." It transpires that devastating errors like these were common.

The only other evidence of Kopachi's existence is the primary school near the memorial. Its windows have rotted and the front door hangs on a single hinge. It is also clear that it was abandoned in haste. Schoolbooks, notebooks, sheets of music and road-safety leaflets litter the hall floor while a single doll – its face blackened and cracked – lies on a cot inside one classroom.

Equally disturbing is the vast artificial lake built near the main plant, which was used to provide water coolant for its four reactors. The lake was frozen in March, but while Chernobyl's reactors were operating its water was warm all year round. Lichen blossomed, so a fish farm was built to populate the lake with catfish that ate the lichen and kept the waters clear.

After the reactor explosion, the lake was showered with radioactive debris which sank to the bottom. Today water has to be pumped constantly from the nearby river Pripyat to stop the lake evaporating in summer and exposing its toxic sediments, which would dry out and be spread by the wind.

However, it is Pripyat that provides the most disturbing evidence of the events of 25 years ago. The city was built to house the families of workers who manned the vast reactor complex at Chernobyl. Four reactors had been built by 1986 and two more were under construction. This was to be the biggest nuclear-power complex in Europe. Fifty thousand people had homes here.

Reactor no 4 blew up in the early hours of April 26, but no one told the people of Pripyat. All that day, children were allowed to play outside, despite the plume of radioactive material emerging from the reactor a few kilometres away.

Of course, there were rumours of a fire, but people had been indoctrinated to believe a reactor accident was impossible – until a fleet of buses arrived at 2pm the next day, 36 hours after the explosion, and Pripyat's people were shipped off to camps and resettlement centres. At the time, they were told they would be allowed back to their homes within three days, but in the end they were never allowed to return.

For an hour, our group wandered round Pripyat, stepping over broken glass and lumps of wood and stone, with the constant chirrup of our radiation counters providing warnings if we strayed too far. Everywhere nature can be seen to be taking back its territory. Trees have erupted through the thick concrete steps of Pripyat's central plaza, while the surrounding woods – which now provide homes for healthy populations of wolves, deer and boar – have spread over every piece of open ground.

Inside the city, books are littered over the grimy floors of the main library while outside, a Ferris wheel – set up to celebrate May Day that year – is slowly rusting.

How many people received fatal doses of radiation in those 36 hours of exposure remains a matter of dispute. Although cheery for most of the trip, Yuri Tatarchuk's anger about the fate of the people of Pripyat at the hands of Ukraine's former Soviet masters became all too clear: "People were told that they had received a radiation dose of no more than 25 rems, enough to cause only minor illness. But that just was not true. They must have got hundreds of rems, fatal doses.

"It was criminal. People should have been given proper diagnoses and proper treatment. They got nothing. At least 5,000 people were badly affected at the time, while women who were pregnant were simply told to have abortions. It was a cruel time."

Today workers are allowed to live in the village of Chernobyl, but for no more than four days at a time. With all four reactors at the plant closed down, they are helping to decontaminate the land within the exclusion zone and to decommission the plant's first three undamaged reactors. As to reactor no 4, the concrete sarcophagus that hides its wrecked, exposed, radioactive core is now crumbling and work has started on a replacement – although Ukraine has made it clear that it will need international assistance to ensure the project's successful completion.

This is a nation that will have to bear the consequences of the world's worst nuclear accident for a long time to come.

As to the comparison between Fukushima and Chernobyl, Tatarchuk is emphatic: "No, it is not as bad in Japan as it was here, not by a long way. But there are lots of similarities. Basically, we had high radiation and no information in 1986, and that seems to be going on once more. That is the pattern when these things happen."

The legacy

-- The Chernobyl reactor was a class of atomic plant known as an RBMK. Of the 17 operating in 1986, only 11 – all in parts of the former Soviet Union – are still in use. Plans for another eight were scrapped and there is international pressure for those still in use to close.

-- Four hundred times more radioactive material was released at Chernobyl than at Hiroshima. The cloud of fallout spread over most of Europe, with the exception of Spain and Portugal.

-- The cost of the disaster has crippled the national budgets of Ukraine and neighbouring Belarus. In 1998, Ukraine said it had already spent US$130 billion cleaning up after the accident while Belarus said it

would have to pay out US$35 billion that year alone. Vast tracts of its farm land had been ruined.

-- Dozens of farms in Britain, mainly in the north-west England's Lake District and in northern Wales, are still restricted in the way they can use land and rear sheep because of radioactive fallout from Chernobyl.

-- Scientists say that radiation will affect the Chernobyl area for 48,000 years although it will be safe enough for humans to begin repopulating the area long before then -- in about 600 years.

http://www.guardian.co.uk/

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Forget Chernobyl at our peril

Those who minimise the dangers and uncertainties in the Japanese nuclear crisis ignore the casualties of the past, argues ***John Vidal.*** *The Fukushima disaster is potentially worse than the 1986 events in Ukraine.*

Image by Jan Grarup/NOOR, courtesy of Greenpeace, shows a mourner in Drosdyn, a village west of Chernobyl.

> *I challenge … any of the pundits now downplaying the risks of radiation to talk to the doctors, the scientists, the mothers, children and villagers who have been left with the consequences of a major nuclear accident.*

Every day there are more setbacks to solving the Japanese nuclear crisis and it's pretty clear that the industry and governments are telling us little; have no idea how long it will take to control; or what the real risk of cumulative contamination may be.

The authorities reassure us by saying there is no immediate danger and a few absolutist environmentalists obsessed with nuclear power because of the urgency to limit emissions repeat the industry mantra that only a few people died at Chernobyl – the worst nuclear accident in history. Those who disagree are smeared and put in the same camp as climate-change deniers.

I prefer the words of Alexey Yablokov, a member of the Russian academy of sciences and adviser to Mikhail Gorbachev at the time of Chernobyl: "When you hear 'no immediate danger' [from nuclear radiation] then you should run away as far and as fast as you can."

Five years ago I visited the still highly contaminated areas of Ukraine and the Belarus border where much of the radioactive plume from Chernobyl descended on April 26, 1986. I challenge the UK chief scientist John Beddington and environmentalists like George Monbiot or any of the pundits now downplaying the risks of radiation to talk to the doctors, the scientists, the mothers, children and villagers who have been left with the consequences of a major nuclear accident.

It was grim. We went from hospital to hospital and from one contaminated village to another. We found deformed and genetically mutated babies in the wards; pitifully sick children in the homes; adolescents with stunted growth and dwarf torsos; foetuses without thighs or fingers and villagers who told us every member of their family was sick.

This was 20 years after the accident but we heard of many unusual clusters of people with rare bone cancers. One doctor, in tears, told us that one in three pregnancies in some places resulted in malformations and that she was overwhelmed by people with immune and endocrine system disorders. Others said they still saw caesium and strontium in the breast milk of mothers living far from the areas thought to be most affected, and significant radiation still in the food chain. Villages testified that "the Chernobyl necklace" – thyroid cancer – was so common as to be unremarkable; many showed signs of accelerated ageing.

The doctors and scientists who have dealt directly with the catastrophe said that the UN International Atomic Energy Agency's "official" toll, through its Chernobyl Forum, of 50 dead and perhaps 4,000 eventual fatalities was insulting and grossly simplistic. The Ukrainian Scientific Centre for Radiation Medicine, which estimated that infant mortality increased 20

to 30% after the accident, said its data had not been accepted by the United Nations because it had not been published in a major scientific journal.

Konstantin Tatuyan, one of the "liquidators" who had helped clean up the plant, told us that nearly all his colleagues had died or had cancers of one sort or another, but that no one had ever asked him for evidence. There was burning resentment at the way the UN, the industry and ill-informed pundits had played down the catastrophe.

While there have been thousands of east European studies into the health effects of radiation from Chernobyl, only a very few have been accepted by the UN, and there have been just a handful of international studies trying to gauge an overall figure. They range from the UN's Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) study (57 direct deaths and 4,000 cancers expected) to the International Physicians for the Prevention of Nuclear War (IPPNW), who estimated that more than 10,000 people had been affected by thyroid cancer alone and a further 50,000 cases could be expected.

Moving up the scale, a 2006 report for Green members of the European Parliament suggested up to 60,000 possible deaths; Greenpeace took the evidence of 52 scientists and estimated the deaths and illnesses to be 93,000 terminal cancers already and perhaps 140,000 more in time. Using other data, the Russian Academy of Medical Sciences declared in 2006 that 212,000 people had died as a direct consequence of Chernobyl.

At the end of 2006, Yablokov and two colleagues, factoring in the worldwide drop in births and increase in cancers seen after the accident, estimated in a study published in the annals of the New York Academy of Sciences that 985,000 people had so far died and the environment had been devastated. Their findings were met with almost complete silence by the World Health Organisation and the industry.

So who can we trust when the estimates swing so wildly? Should we believe the empirical evidence of the doctors; or governments and industrialists backed by their PR companies? So politicised has nuclear energy become, that you can now pick and choose your data, rubbish your opponents, and ignore anything you do not like. The fact is we may never know the truth about Chernobyl because the records are lost, thousands of people from 24 countries who cleaned up the site have dispersed across the vast former Soviet Union, and many people have died.

Fukushima is not Chernobyl, but it is potentially worse. It is a multiple reactor catastrophe happening within 240 kilometres of a metropolis of 30 million people. If it happened at the Sellafield site in north-western England, there would be panic in every major city in Britain. We still don't know the final outcome but to hear experts claiming that nuclear radiation is not that serious, or that this accident proves the need for nuclear power, is nothing short of disgraceful.

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After Fukushima, risks beyond radiation

The safety of atomic energy has become a hot topic for public discussion in China since the nuclear crisis in Japan. But, writes ***Chen Jiliang****, China also needs to consider the economics – and the security dimension – of the nuclear debate.*


Image by Greenpeace

It took the recent crisis at the Fukushima nuclear plant in Japan to make atomic energy a topic for public discussion in China. Safety issues have been at the core of that debate. China's ambitious nuclear power programme, further codified in the 12th Five-Year Plan, suddenly began to panic ordinary people. It became even worse when officials or industry experts attempted to offer their explanations. Poor communications strategies – and widespread public distrust of experts – meant that confidence in the technology only declined. Nuclear experts needed to justify their work to the sceptical public for the first time, leaving them frustrated with what they perceived as a scientifically illiterate Chinese public.

The incident at Fukushima almost coincided with the 25-year anniversary of the Chernobyl disaster in the Ukraine. The Heinrich Böll Foundation, affiliated with the German Green Party [*the author is a project officer at their Beijing office*], has published a series of reports about nuclear power to mark that historic anniversary, looking at the use of nuclear power in terms of its economics, the effect on weapons proliferation and its comparison with renewable energy sources.

The reports did not only focus on safety: this is but one variable in the overall analysis. This may be because Europe has seen a lot more debate about nuclear safety than China in the last few decades – and also because the urgency of addressing climate change has changed the terms of the discussion about atomic energy. Either way, the facts in these reports provide a useful counterpoint to the firm beliefs of some regarding the safety and viability of nuclear power.

> *The report concludes that nuclear power spends huge amounts of money that could otherwise be invested in cleaner, faster-to-develop sources of renewable energy.*

One report, *The Economics of Nuclear Power: An Update*, by Steve Thomas, emphasises the costs of nuclear safety. Safety is why the cost of nuclear power stations has increased fivefold in the last decade: banks will not take on the risks associated with funding nuclear-power stations. For example, six of Wall Street's largest investment banks told the US Department of Energy that unless taxpayers underwrite 100% of the risks, they will not lend to new nuclear projects. The report also finds that where the power sector is a regulated monopoly, the real cost of capital will be relatively low – 5% to 8%. But where there is a competitive market, the cost of capital will be much higher – at least 15%.

Meanwhile, the costs of constructing a nuclear power plant – not including decommissioning costs, or the processing and handling of nuclear waste – represent 70% of total costs. International experience suggests that modern reactors require huge on-site construction, for which cost control is problematic – it often runs over budget. The designs may be changed

during construction – for example, new designs may have not been certified when construction started, or an accident at an existing plant may require changes to those being built. Delays are also common. There seems to be little "learning curve" or indeed "economy of scale" in nuclear power.

The author concludes that while nuclear power plant designs can in theory meet the safety standards of regulators, the costs are prohibitive. Nuclear power plants can only be built when the government is prepared to ignore the results of public consultation and provide large subsidies. Moreover, the bills for decommissioning and dealing with nuclear waste are also left for the taxpayer to pick up.

There are huge opportunity costs associated with investing in nuclear power instead of renewable energy. In another report, *Systems for Change: Nuclear Power vs. Energy Efficiency + Renewables?*, by Antony Frogatt and Mycle Schneider, the authors argue that in the first 15 years of their development in the United States both nuclear and wind power produced large amounts of energy – 2.6 billion kilowatt-hours in the case of nuclear, 1.9 billion for wind – but nuclear power received 40 times as much money in subsidies (US$39.4 billion, as opposed to $900 million). The report concludes that nuclear power spends huge amounts of money that could otherwise be invested in cleaner, faster-to-develop sources of renewable energy.

As for the common view that nuclear energy is a large and stable producer of energy, the authors point out that such large, centralised power generation often produces surplus energy that cannot be saved. Increasing renewable-energy generating capacity requires flexible, medium-load infrastructure, rather than inflexible heavy-load power generating plants. In their vision for low-carbon generation, the authors suggest bi-directional grids so that energy consumers can also store and send power back to the grid. The smart meters and grids for this are already under development.

Finally, nuclear power can also present a threat to security and social stability. This is the conclusion of *Nuclear Weapons and Nuclear Energy – Siamese Twins or Double Zero Solution*, Otfried Nassauer. Of course, atomic energy and nuclear weapons are different things, but there is little difference between refining uranium for civil and military applications – the former can easily be adapted for the latter use.

It is hard to tell during the early stages of civil nuclear programmes if there are concealed military aims. Nuclear weapons programmes in France, Israel, North Korea and South Africa all started with civil nuclear programmes. There is a lack of international consensus about whether Iran's nuclear programme is peaceful or not. The report suggests, therefore, that there is a contradiction between two of US president Barack Obama's stated intentions: on the one hand to reduce nuclear proliferation, while on the other to expand the peaceful use of atomic energy. Even if there were no safety issues with the storage and handling of spent nuclear fuel or the safety and security of nuclear power plants, the expansion of nuclear power means the spread of nuclear materials and related technical knowledge.

Given the security situation in the world today, it is hard to be sure that nuclear know-how or materials will not fall into the hands of extremists, especially where there are unstable governments. There is the risk, for example, of someone constructing a "dirty bomb" that uses radioactive materials. Some incidents in China have shown us that even seemingly ordinary citizens can, in extreme circumstances, take terrible vengeance on society at large.

Therefore, there are more issues at stake than just the safe operation of nuclear power plants. People should not ignore other issues, such as social stability, the environment and economic sustainability. China's policy-makers and nuclear experts are probably confident in the safe operation of China's nuclear power sector. But the development of nuclear power is not only a technical issue: if we do not take economic,

environmental and social factors into account in the decision-making process, we risk losing the confidence of the public – and may make them shoulder difficult long-term risks.

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