Reliability and nuclear power

Way Kuo

A 9.0-magnitude earthquake and the tsunami it triggered hit the north-east coast of Japan on 11 March, 2011, causing widespread death and destruction, including successive hydrogen explosions in three reactors and one spent fuel tank at the Fukushima Daiichi nuclear plant.

The released radiation caused a world-wide nuclear phobia. Some overseas rescue teams abandoned Japan for fear of radiation exposure and people in neighbouring countries scrambled to buy iodine and iodized salt for fear of nuclear particles floating across from Japan on the wind.

Although people in Hong Kong for the most part knew there was only a slim chance radioactive substances could reach the territory, many still rushed to the supermarkets to purchase Japanese milk powder and soya sauce, fearing future supplies might be contaminated.

As a rule, any disaster is likely to cause panic, and it is particularly so with nuclear energy-related crises. When I first came to City University of Hong Kong a couple of years ago, I delivered my first academic talk on nuclear safety. But only a few people paid heed. With the nuclear crisis in Japan, many people are now gripped with fear, reminding me of the Three Mile Island incident in the US in 1979. At that time, Americans panicked, too, in no less degree than the fear-haunted people today. The accident this time is as grave as that of the Three Mile Island accident (On 12 April, a month after the accident, the Japanese government raised the crisis level to seven), and the fear is understandable since people generally don't know much about nuclear energy.

Nuclear accidents in history

At present there are 443 nuclear reactors in 47 countries. Japan possesses 55, ranking the nation among the highest in terms of the utilisation of nuclear power. They provide 29% of the total national power supply. The top-ranking countries are Lithuania and France, both over 75%, even though Lithuania has no nuclear reactors of its own.

There have been several serious nuclear accidents in the past, the most critical being the Three Mile Island accident in the US in 1979 and Chernobyl in the former

Soviet Union in 1986. The latter is the only nuclear accident to date that has inflicted heavy human casualties. It should be noted, though, the design and construction of the Chernobyl plant was far from compliant with international standards and should not be counted as a standard nuclear power plant.

There have been three accidents in the nuclear power industry in Japan since the first plant opened in 1966: Tsuruga nuclear power plant in 1981, Monju nuclear reactor in 1995, and the Tokai Village nuclear accident in 1999. None inflicted serious casualties on civilians.

Nuclear power plants are not atomic bombs

One of the chief reasons behind the panic comes from a fear of atomic bombs. Before the end of World War II, two US atomic bombs were dropped on Japan. The ensuing devastation left an indelible shadow and bitter memories. However, as the fire in the stove at home is different from the fire burning grass on the waste land, so a nuclear power plant is not an atomic bomb. The uranium concentration in a nuclear power plant is not high; it is confined within the solid, unventilated furnace where a controlled nuclear reaction takes place. What's more, the regular cement wall outside the nuclear reactor is two to three meters thick. In contrast, the uranium concentration in an atomic bomb is high and hard to control.

What worries people most in Japan is radioactive substances contaminating water sources. So far, this has not happened, but in case it does, there is no reason for panic as people living nearby have been evacuated. The negative effects would be far less devastating than those of atomic bombs.

Is nuclear power reliable?

The use of nuclear energy to generate electricity has been controversial ever since the first power stations opened, but the Fukushima nuclear accident has brought these concerns sharply into the public eye. People are anxious to know more about the chances of similar accidents occurring in the future and the potential impact. So is nuclear power reliable enough?

It should be noted that the nuclear industry adheres to strict safety standards. In 1975, *WASH-1400*, also known as the *Rasmussen Report*, was issued in the US. I read with great interest the accounts of all the possible scenarios for accidents, the probabilities of such accidents and a detailed analysis of possible reasons behind the

accidents. In 2007, the Nuclear Regulatory Commission (NRC) published its *State-of-the-Art Reactor Consequence Analysis* (SOARCA), which uses computer simulations to illustrate potential accidents in nuclear power plants. It has been deemed a guideline for nuclear power safety ever since.

Reliability is a mode of assessment. In the manufacturing industry, reliability has a close relationship with product warranty. It includes elements such as product cycle analysis and risk evaluation. As far as nuclear power is concerned, reliability is achieved by assessing every link of the whole process for possible failure, which is similar to how and what SOARCA records.

Nuclear power is a mature industry now. Both second- and third-generation nuclear power stations are built according to sound scientific theories and safe technologies. The probability of a nuclear accident is minimal. B. L. Cohen, a well-known physicist, concluded in a study on life expectancy and radiation risk from nuclear power plants that even if a person lived his or her entire life in the vicinity of a nuclear power plant, the impact on life expectancy, on the average, would be far less than that due to non-nuclear-related accidents.

"Second-hand contamination" unfounded

Only people living close to the source of a radiation leak from a nuclear plant are in danger. Nuclear radiation harms the human body only when it accumulates to a certain point. In the event of an accident with off-site risk, people should be evacuated outside the 20-kilometer radius. Medical treatment for radiation sickness is required for anyone who stays within that 16-kilometre radius for several hours. The consequences of exposure to high levels of radiation include infertility, thyroid carcinoma and other cancers, depending on the levels of exposure.

The fact is, small amounts of radioactive substances attached to shoes and clothing can be washed off easily, and will not pose any harm to human health.

The Three Mile Island nuclear accident in March 1979 was rated a five on a seven-point scale, according to the International Atomic Energy Agency. Tracking reports by the NRC and several other independent research reports suggest that the highest background radiation dose was between 100–125mrems, and the accumulated radiation the two million residents in the vicinity were exposed to was similar to the average natural radiation we are exposed to every year. (We should note that radiation

from an X-ray is 6mrems). These reports suggest that Japan's neighbours need not worry about radiation leaking from the nuclear power plant.

Nuclear power plants: economic and safe

Rapid economic development has aggravated the global energy crisis. Every country is looking for alternative energy sources, of which nuclear energy is a top priority for many. Under current conditions, nuclear power still boasts unrivaled merits and is the most economical and the cleanest power source.

Nuclear power and coal-derived fuel rank among the most economical forms of energy. The average is about US$0.022 per kilowatt-hour, less than half the cost of petrol and natural gas. However, according to statistics issued by the World Nuclear Association (WNA), China spends 6% of its GDP every year dealing with pollution caused by burning coal and oil.

In addition, a nuclear power plant is one of the safest workplaces you can find. The probability of a workplace accident is higher in the finance, insurance or real estate development sectors. For every two million working hours, the ratio of an accident in a nuclear power plant is less than one versus the average of 45 in the general manufacturing industry.

According to WNA statistics, prior to the Fukushima nuclear accident, only two severe nuclear accidents, namely Chernobyl and Three Mile Island, occurred throughout the accumulated 14,000 operating years of commercial nuclear reactors in 32 countries.

In addition, viewed in terms of energy value, nuclear power generates less harmful substances, such as carbon dioxide, than other energy sources do. In fact, the environmental value of nuclear power is far higher than that of other energy sources, as illustrated in the following table.

Highest Environmental Value of Different Energy Resources

Table: The Highest Environmental Value of Different Energy Resources

	NO_X	SO_X	Hg	CO_2	Total Value	Present Value
	(US$/kw/year)				(US$/kw)	

nuclear energy	11.6	5.3	12.0	61.2	90.0	750.1
wind energy	2.2	0.7	1.6	17.1	21.6	180.1
solar energy	1.5	0.3	0.8	13.7	16.2	135.3
bioenergy	-4.3	3.7	8.5	51.5	59.4	495.1

Source：Electric Power Research Institute, 2003

Monitoring imported Japanese food

Concerns over food imports from Japan, while understandable, are not justified upon a close examination of a number of factors. There are, after all, safety checks on all imported food from Japan using special detection devices for radioactivity, just as there are X-ray checks at the airport on luggage.
These checks, though, are not necessary if the fuel rods in the stricken reactors have not yet melted, and we should remember that radioactive substances cannot produce any negative effects without a medium. While “extremely low levels” of radioactive iodine have been detected in the air over many neighboring countries and regions, it is unlikely to pose any threat to public health and environment.

In any case, a lot of food is subjected to small doses of radiation as part of the overall manufacturing process. Food irradiation (exposing food to ionizing radiation) is widely used for sterilising, preventing decay and killing insects. The milk we drink and many of the green vegetables we eat have been subject to similar treatment.

Human factors

Even if nuclear power plants are built on a sound scientific and engineering basis, the biggest uncertainty is the human factor. Both the Chernobyl and Three Mile Island nuclear accidents happened at midnight and were caused by human error. In all kinds of systems, the interaction of humans with the system is crucial to safety. In a very big system, we must locate bottlenecks and implement radical reforms where necessary. Professional training is an ongoing process, so ensuring staff members are well-trained is a better guarantee of safety than reliance on high-tech equipment.

It is of paramount importance to remain calm in the face of an imminent crisis. Getting to know more about nuclear power plants will enable us to make sound judgments in such circumstances. However, knowledge about nuclear power is usually something beyond the reach of the average person, and this is the cause of the panic. Therefore, while the nuclear industry and nuclear power plants need to enhance safety measures, they should also promote popular science education on nuclear energy.

Pay heed to maintenance

We should also increase the transparency of the operation and management of nuclear facilities to dispel the psychological pressure on the general population. As we know, panic in certain sectors of the local community after the nuclear accident in Japan had much to do with the lack of perceived transparency. As a result, people questioned the credibility of the released information, creating room for speculation and anxiety. People prefer to err on the side of caution.

The Fukushima nuclear plant has been running for 40 years, its designed limit. It remains to be seen whether there was any negligence in the maintenance strategy. We have now come to realise more keenly than ever before the importance of vigilance and maintenance. Using a car safety allusion, we expect to use spare tires at some point when we are driving. If dozens of nuclear plants are running at the same time, there should be several spare systems and power provision centres ready to serve as replacements at any time. Constant checks should be conducted on management, operation and contingency measures to ensure smooth functionality.

Impact of nuclear science, technologies on Hong Kong

Nuclear power constitutes 23% of Hong Kong's total power supply, and is expected to increase to 50% by 2020 to help curtail the release of carbon dioxides. As it is impossible to depend on any alternative power supply within a short period, banning nuclear power would mean limiting the use of electricity and intermittent blackouts, gravely impacting life in Hong Kong. Needless to say, we should investigate developing technologies for renewable energies and advocate a new energy-efficient lifestyle.

But nuclear energy still ranks among the major energy sources even after taking into account all the factors, including the negative impacts of alternative

energy technologies and cost, the pollution of non-nuclear power to the environment, the accumulated experience derived from accidents, breakthroughs in science and technologies, new advances in industrial techniques, etc.

I believe that, learning the lessons from Japan, the Hong Kong people have come to see that Hong Kong is not immune to changes in neighbouring countries and regions. In a globalised environment, what happens in the region will affect the local economies as well as political and social stability. In modern society, we need to know more about science and technology and promote scientific and technological advancement to solve the problems confronting humanity rather fear science and technology due to a lack of understanding.

Otherwise, we will not be able to enjoy the quality of life that comes with science and technology.

Professor Way Kuo is President of City University of Hong Kong and University Distinguished Professor. He is a Foreign Member of the Chinese Academy of Engineering, a Member of Academia Sinica, Taiwan and the US National Academy of Engineering. Professor Kuo worked in the management team for Oak Ridge National Laboratory. He currently serves as Editor-in-Chief of IEEE Transactions on Reliability.