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雑誌名	情報研究 : 関西大学総合情報学部紀要
巻	41
ページ	1-23
発行年	2014-08-08
URL	http://hdl.handle.net/10112/8460

関西大学総合情報学部紀要「情報研究」第41号

Global Boiling by Nuclear Heated Ocean: Unstoppable Atomic Generations

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Abstract

Hiroyuki Itsuki has said that Fukushima was a ‘second war defeat’. Japan, which suffered the atomic bombing of ‘Hiroshima’ and ‘Nagasaki’ in the Second World War, was once again visited by a nuclear incident at Fukushima. After the world war, the state was defeated but the natural environment was preserved. Conversely, at Fukushima, the natural environment was lost and people were robbed of their livelihood, with the state alone remaining intact. Historically, the International Atomic Energy Agency (IAEA) have taken only retrospective action in the event of nuclear-related accidents, disasters, or mishaps, while current law is insufficient and ineffectual in the face of the nuclear issue. Meanwhile, the management of the electric-power companies in charge of nuclear operations, such as the Tokyo Electric Power Company (TEPCO) in the case of the Fukushima nuclear accident, has also been lax both in its preventive measures against accidents and disasters and in its risk awareness1). Even after the accident, its response can only be called inadequate.

This article reviews, firstly, outlines the ‘unstoppable’ nature of nuclear generation as exemplified by the lifecycle of nuclear reactor technology, the decommissioning of reactors, and the nuclear-waste disposal problem; secondly, traces the roles in the JCO nuclear-fuel criticality accident of failed management in the form of the power companies, and government in the form of the ‘nuclear-electricity regulatory authorities’ and ‘fuzzy policy’; finally, highlights ‘ocean-temperature’ rise in the northern hemisphere, specifically the North Pacific, Arctic and North Atlantic, perhaps as a result of the thermal effluent from 435 nuclear reactors in the northern hemisphere which is an insidious product of today’s nuclear industry.

Keywords: unsought consequences, unexpected results, governance and compliance, risk/crisis management

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† Original work: Atsuji S. et. al., “Un–safety: Systems Pathology of the Fukushima Nuclear Catastrophe,” *ISSS Proceedings*, 2013.

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I. Limits of Crisis Management by the Aging Reactors

(1) Systemic Lifecycle of a Nuclear Power Station

The disaster that occurred in March 2011 at the Fukushima nuclear power station in Japan sent shock waves around the world. With this now the third major nuclear-power disaster, following Three Mile Island in America and Chernobyl in the former Soviet Union2), the safety of nuclear power has begun to be questioned. In western countries and other developed nations that have introduced nuclear power, the disaster has raised the issue of ‘aging nuclear reactors’, whose environmental impact, including the issue of ‘decommissioning of reactors’, has become a concern.

Of the world’s 441 nuclear power reactors, 435 are concentrated in the northern hemisphere, leaving only six in the southern hemisphere. According to Dr. Koide of Kyoto University, the volume of the resulting thermal effluent from a plant in the average ‘1-million kW output range is 70 tons/second of water coolant’, which has been heated by 7°C. Assuming that the world’s nuclear reactors operate at 70 percent of capacity, with an average operating period to date of ‘31 years’, it is estimated that ‘a cumulative total of 17.9 trillion tons of water has been heated by 7°C’. That is enough to form in the northern hemisphere a surface layer of around ‘11 cm that has been warmed by 7°C, or a surface layer of 77 cm warmed by 1°C’.

Compared to atmospheric warming by CO_2, heat energy retained in seawater, because of the latter’s specific heat, is more easily stored and less easily released, which poses the possibility that warming from nuclear power is causing a ‘global boiling’ phenomenon in which the world’s oceans, especially in the northern hemisphere, are overheating. According to the analysis of the research by Atsuji’s KAKEN group funded by a Japanese government foundation, the possibility that the year-by-year accumulation of such thermal effluent from nuclear power stations produces large bodies of water in the seas of the northern hemisphere while having a considerable influence on abnormal weather patterns arising from a process of ‘teleconnection’ triggered by North Atlantic hotspots, cannot be excluded either qualitatively or quantitatively. This could be considered as like the environmental hormones referred to by T. Colborn. It cannot therefore be ruled out that the ‘human-made disaster’ of nuclear thermal effluent, building up year by year, has precipitated ‘global warming’, abnormal weather patterns, and natural disasters such as summer blizzards, major floods, tornados, ‘super-typhoons’ and ‘El Niño-La Niña phenomena’ with the ironic result that ‘a chain of human-made disasters adds up to a natural disaster’.

Figure 1 charts the world’s nuclear power stations by duration of operation and shows a large number that have been operating for 30 years or more in North America, Europe, and Japan. Of those stations currently in operation, approximately 37 percent are in the ‘aging’ category—that is,

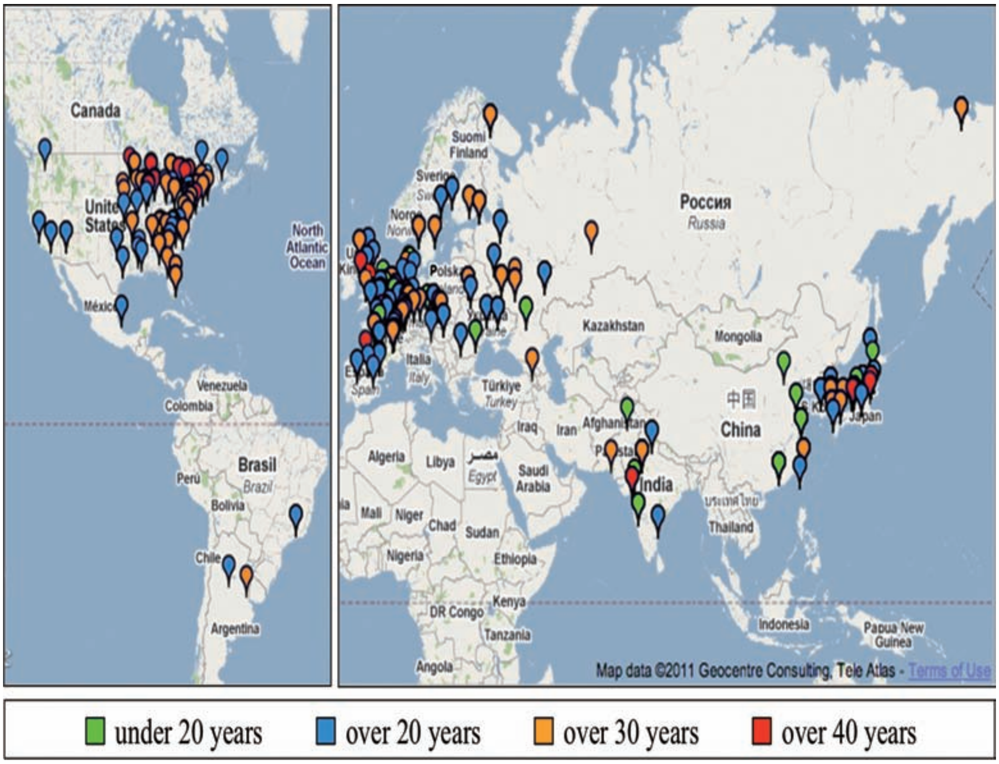

Figure 1 The world's aging nuclear reactors (2011)

Source: World Nuclear Association, Nuclear Database (http://world-nuclear.org/nucleardatabase/advanced.aspx) Accessed March 2011. (Revised by S. Atsuji and R. Fujimoto.)

30 years old or more—in which the lifecycle has been extended beyond the normal operational lifespan of nuclear reactors. Meanwhile, standards for the decommissioning of nuclear reactors do not exist either at the international or the national level, and in the profit-driven and highly lucrative business of nuclear-power generation, there is a history of operational lifespan being extended without allowing for 'decommissioning' and decontamination costs or accident clear-up costs. Calculations of costs have failed to consider expenditures and time periods falling outside the operational lifespan, at the planning and construction stage or in the dismantling and decommissioning of reactors. Table 1 summarizes the systemic lifecycle of a nuclear power station including these stages. Normally, the lifecycle of a nuclear power plant has been set at 20 years, but many countries extend the operational lifespan beyond 40 years. The United States has permitted a 20-year extension of a nuclear power plant already in operation for 40 years to a total of 60 years. Meanwhile, in Japan, the approval plan of extensions up to 60 years had been suggested in October 2010, the year before the Fukushima nuclear accident.

Table 1 Systemic lifecycle of a nuclear power station

Planning stage		Construction stage	Operation stage	Reactor decommissioning stage			Dismantling and removal		Total no. of years
Planning	Application	Construction operations	Operation and inspection	Nuclear fuel discharge	System decontamination	Safe storage	Interiors	Buildings	
Approx. 4 years			20–40 years*	20–30 years* not including disposal of spent fuel					80–100 years

*Operational lifespan: 60 years where extension permitted.
Source: legislation on nuclear source materials, nuclear fuel materials, and nuclear reactor regulations (extract from K. Ueda and S. Atsuji).

The period required for the decommissioning of nuclear reactors is said to be 40 years, which means that the lifecycle from construction through to decommissioning, even excluding the disposal of spent nuclear fuel, is more than 80 years. The cost of decommissioning is estimated at around 350–480 million dollars for a small reactor (in the 500,000 kW range), around 430–610 million dollars for a medium reactor (in the 800,000 kW range), and around 560–760 million dollars for a large reactor (in the 1.1-million-kW range)3). Moreover, the planning and application process—from the establishment of a nuclear power station through to the decommissioning of the reactors, including approval and licensing procedures with the regulatory government authority—is complicated. It is also crucial to take into account the costs and time needed for the substrata inspection required before the construction of an electricity-generating station, the trial operation required before full operation, and the ‘radiation-decontamination operations’ necessary at the time of decommissioning, while nuclear waste in the form of spent nuclear fuel also consumes massive costs and time. The decommissioning of nuclear reactors has thus become a global issue today.

Spent nuclear fuel is stored for three to five years in a ‘cold storage pool’ within the station. Subsequent processes differ by country, but the waste is generally sent to a reprocessing plant to extract re-usable uranium and plutonium, after which it is subject to long-term storage, for instance in an underground facility at a treatment plant for highly radioactive waste. In Japan, highly radioactive waste is vitrified and kept in cold storage for 30–50 years, then disposed of underground through burial at a depth of at least 300 m in the geological strata. In November 2013, former prime minister Junichirō Koizumi called for an immediate end to nuclear power. To support his argument, he cited the fact that there was still no decision made on a ‘spent-nuclear-fuel storage’ facility and, despite the yearly increasing volume of nuclear waste, no confirmed plans as to the disposal system and technology to be used or the location of the disposal site.

(2) Unstoppable Nuclear Power Generation

Today, in the wake of Japan’s Fukushima nuclear accident, the world’s nuclear power stations are under increasing scrutiny from the viewpoint of safety. Fukushima has taught the world that accidents could involve not only natural disasters such as earthquakes, tsunamis, typhoons, torrential rain, flooding, and drought, but also terrorism, war, coup d'état or other events that, instead of attacking the nuclear reactor itself, interrupt the functioning of the electricity-generating facilities used for cooling, causing the reactor to go into meltdown. As a result, the possibility of nuclear-power facilities becoming terrorist targets has been pointed out. In France, 'Greenpeace' activists made an experimental break-in at a nuclear reactor building, while in the United States a group of three elderly protestors reportedly penetrated a nuclear reactor facility supposedly under heavy security. They are finding the 'security holes'.

From the start, the systemic lifecycle of nuclear-power generators, from initiation to the decommissioning of reactors, the disposal of radioactive waste, and other aspects, has remained a matter of uncertainty. As shown above in Table 1 (Systemic Lifecycle of a Nuclear Power Station), four years were estimated for the initiation including the initial operating period, and 20–40 years for operation, but as noted above the original 20-year lifespan of a nuclear power station has been extended in a common worldwide development. When decommissioning of reactors and radioactive

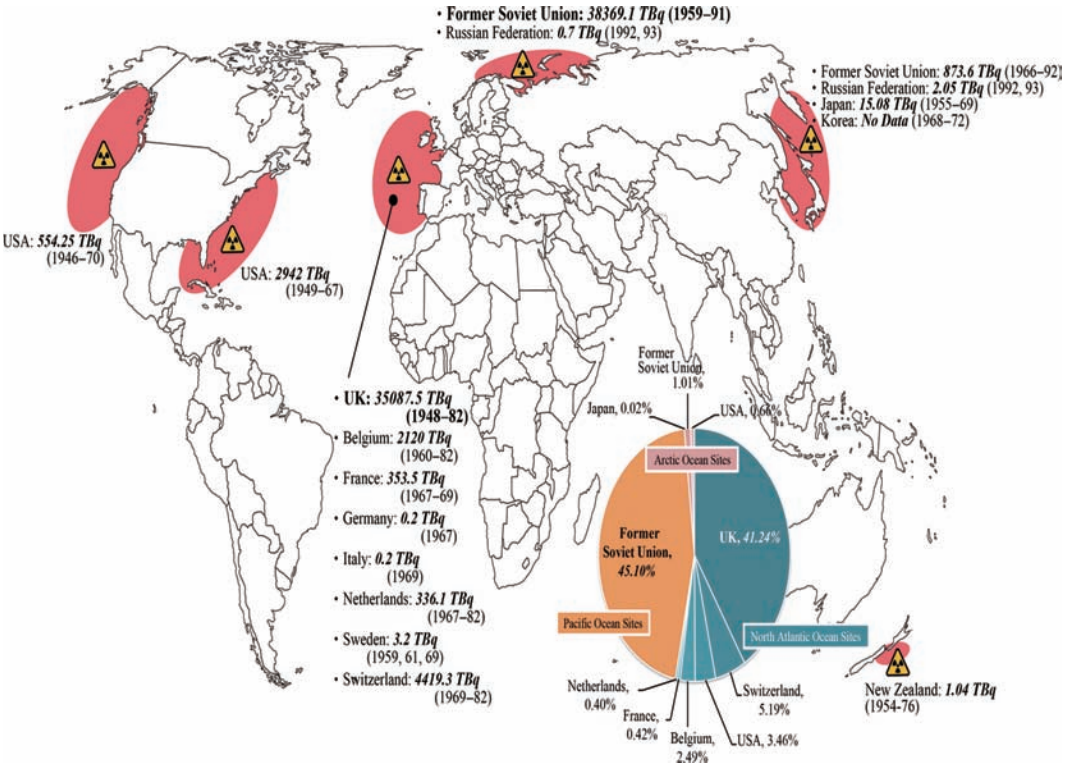

Figure 2 Cumulative total of sea-disposed nuclear waste

Source: IAEA, "Inventory of Radioactive Waste Disposals at Sea", *IAEA-TECDOC-1105*, August 1999. (http://www-pub.iaea.org/MTCD/publications/PDF/te_1105_prn.pdf) Revised by S. Atsuji and R. Fujimoto.

half-life are taken into account, we arrive at a period of more than 100 years of continuing cost and labor requirements. These are not all included in calculations of the unit cost of electricity generation. There is already a history of worldwide marine disposal of drums containing radioactive nuclear waste, the cumulative total of which over 50 years has exceeded 100,000 tons according to the IAEA4). Figure 2 shows the cumulative total of sea-disposed nuclear waste by some countries.

In 1993, when an international treaty banned marine disposal of nuclear waste, America, Germany, Finland, and other countries built facilities for deep underground storage. In some cases, for instance at 'Areva's La Hague' facility in France, disposal in undersea pipelines or similar was reported. The operation of nuclear power stations thus invites Barnard's 'unsought consequences'. Nuclear power's unsought consequences or 'unexpected results' (P. F. Drucker)5) are represented in the problematic by-products of radioactive contamination from station operation: in addition to (1) limits to the manageability of nuclear power (technological issues of metal fatigue and deterioration) we also face (2) radioactive contamination, and (3) disposal of nuclear waste and decommissioning of reactors when operation ceases (legislation, systems, technology). Additionally, there is (4) the trend for local communities to petition for continued operation, for instance where local businesses have been commissioned with related projects or local governments have received legally mandated payments in return for the exploitation of electric-power resources. Thus, once a nuclear power station has begun operation, in almost all cases it continues to operate even after the inspection period is finished. This means that they are in the generation of 'unstoppable nuclear'. Once a nuclear power station is in place, it is permanent.

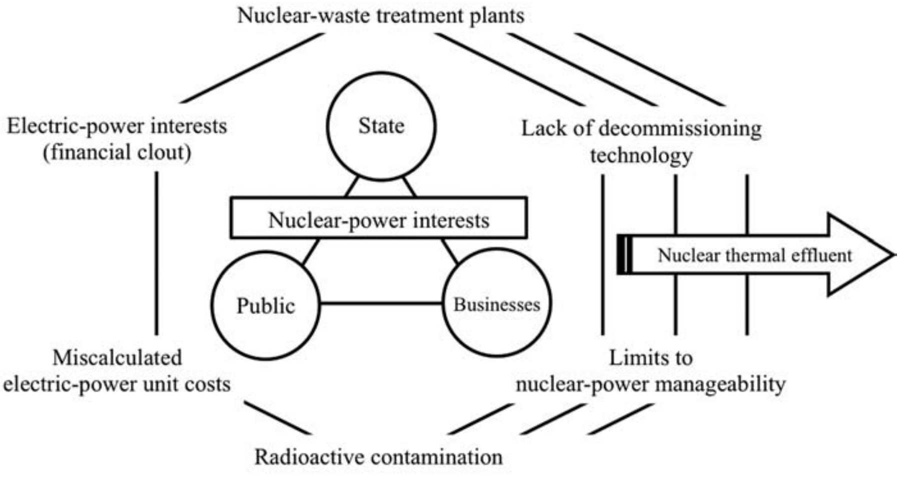

Figure 3 Unstoppable nuclear power generation

Underlying the ‘unstoppability’ of nuclear power generation outlined in Figure 3 are (1) a lack of standards for the decommissioning of reactor technology; (2) ‘failure’ to decide on sites for disposal of accumulating nuclear waste; (3) softening up of communities local to nuclear-power facilities with financial incentives through payment of compensation, consolation money, etc; (4) calculation of electricity-generation unit costs without factoring in costs for decommissioning of reactors, ‘decontamination, or waste treatment’; (5) falsification of radioactive-contamination measurements; and (6) limits to the operational manageability of nuclear power stations and ‘concealment’ of the environmental impact of large amounts of thermal effluent. This illustrates the interconnected factors around the unstoppability of nuclear power.

Moreover, a stakeholder group has formed around the vested interests of local communities, power companies, and the regulatory ‘government authorities’ in charge of approval and ‘licensing operations’. Massive grants from central government are not only allotted to local businesses and residents and electric-power-related associations and companies, but are also distributed in the world of academia to nuclear-power research organizations and as expenses to related corporations. Among the parties involved, this is perhaps accepted to a large extent as a kind of ‘tacit payment for inconvenience’, ‘danger money’, or compensation for contamination, but as was shown by the Fukushima nuclear accident, these short-term handouts are no consolation when the worst comes to pass and the living environment, agricultural land, fishing grounds, and other resources are all lost semi-permanently.

However, ‘stakeholders’ with connections of interest to nuclear power are not limited to the state, commercial enterprises, and local communities. The radioactive contamination that rains down on local people can cross borders to cause exposure in other areas, as at Chernobyl. It was reported by the investigation after the Chernobyl accident that radioactivity had spread across Europe6). In the Como region of Italy, the entire rabbit population was culled, while restrictions were placed on the export of German dairy products such as cheese and powdered milk. However, today, in Belarus and the Chernobyl district of the Ukraine, livestock and dairy farmers continue to drink contaminated milk. Of particular note is that residents of communities close to Chernobyl, and especially the children, have rates of leukemia and thyroid cancer almost five times the normal level. Following the recent Fukushima nuclear accident, radioactive contamination has been detected in coastal waters and is becoming an international issue through spread by sea currents, creating a situation for which no restitution is possible. Beyond this, what kind of issues lie latent in regular nuclear-power-station effluent, which contains waste heat?

(3) Nuclear-power Disasters and Radioactive Contamination (Damage to Human Health)

In the Fukushima nuclear accident precipitated by the Great East Japan Earthquake of 2011, and other nuclear-power-related accidents and disasters such as the 1999 JCO criticality accident, the Chernobyl accident in the former Soviet Union, and the Three Mile Island accident in the United States, the radiation that is released in the form of cesium, strontium, and other ‘elements destroys DNA’, not only taking human life but also depriving people of their livelihoods. Radioactive contamination from nuclear power stations and other sources threatens human life and property and infringes on the right to life and human rights, thereby violating constitutional law; cancer and other harms resulting from radiation inflict damage on life and future generations so that it also violates criminal law; by destroying the living environment and communities and undermining livelihoods by damaging workplaces, agricultural land, fishing grounds, and other environments, it also violates civil law. The problem of radioactive contamination from nuclear power stations is a supralegal issue not susceptible to control by current law.

Today, Fukushima’s contaminated waters present a difficult problem. With Tokyo chosen as the host city of the 2020 Olympics, the International Olympic Committee views with misgiving prime minister Shinzō Abe’s statement that ‘the radioactive contamination at Fukushima is completely under control’. At present, as of the end of 2013, accumulated in the contaminated-water storage tanks are 334,000 tons of effluent, enough to fill 800 25-meter swimming pools7). The cumulative total of 27,000 trillion becquerels of radioactive contamination that it has already released is said to be equivalent to approximately ‘1,100 times that of a Hiroshima-type atomic bomb’, causing concern over the damage to local communities, human health, and the ecosystem. To illustrate the potential threat, Table 2 summarizes the average amount of the main nuclear species contained per ton of spent nuclear fuel, their half-life, and the potential damage to human health.

Historically, against the background of the nuclear arms race during the ‘Cold War’ between the United States and the Soviet Union, nuclear waste (plutonium, californium, yellow cake, depleted uranium) from nuclear-power facilities under the western ‘nuclear umbrella’ was mostly collected by the United States as material for intercontinental ballistic missiles and other nuclear weapons. However, after the launch of talks under the Strategic Arms Reduction Treaty (START) between the United States and the Soviet Union, nuclear waste had to be dealt with by the individual country.

The problems associated with the aging of nuclear power stations are not limited to the decommissioning of reactors and the treatment of nuclear waste, but also involve the elevated risk of nuclear-related accidents and disasters as well as terrorism and related incidents. Accidents have already taken place at the Three Mile Island nuclear power station in the United States8), the Chernobyl nuclear power station in the former Soviet Union, and during the crisis accompanying the atmospheric reentry of the nuclear-reactor-equipped ‘Soviet space station Mir’. In each of these cases involving the nuclear-power issues of the superpowers, the facts were not sufficiently reported to other countries. However, with the collapse of the former Soviet Union, the details of the Chernobyl

Table 2 Half-life and damage to human body of species contained in spent nuclear fuel

Nuclear species	Half-life	Content per 1000 kg of concentrated spent fuel (kg)	Site of accumulation in human body / biological half-life
Uranium 238	4.48 billion years	950 kg	Bone / 50 years, liver / 20 years
Uranium 235	704 million years	10 kg	Bone / 50 years, liver / 20 years
Plutonium 239	24,000 years	10 kg	Bone / 50 years, liver / 20 years, reproductive glands / unknown
Strontium 90	29.1 years	26 kg	Bone / 50 years
Cesium 134/137	2 years / 30.1 years		Muscle, whole body / 2–110 days
Tritium	12.3 years	—	Whole body / 10–45 days
Iodine 129/131	15.7 million years / 8 days	1.2 kg	Thyroid / 80 days Rest of body / 12 days
Americium 241	433 years	0.6 kg	Bone / 50 years, liver / 20 years
Neptunium 237	2.14 million years		
Curium 242	162.8 days		

Notes

1. The above table covers the main nuclear species contained in spent nuclear fuel and is not specific to the Fukushima accident, which has been confirmed to involve 31 radioactive substances.
2. In Japan and other countries, after extraction at the reprocessing plant of reusable uranium and plutonium, the remaining material is buried in concrete.
3. Spent nuclear fuel may be directly buried in concrete depending on the country.

Source: website of Citizens' Nuclear Information Center (http://www.cnic.jp/) Accessed December 2013. (Extract from K. Ueda and S. Atsuji).

accident came to light, and it was reported to have caused the 'China syndrome'. This is the name for the phenomenon which occurs when a nuclear reactor goes out of control and melts and the gravitational force of the heavy uranium sends it sinking toward the center of the earth. It was found out that, as the uncontrollable nuclear reactor reached a high temperature and the building of the Chernobyl station subsided9), soldiers of the former Soviet army injected ultracooled liquid nitrogen into the ground below the reactor to prevent the reactor core from sinking. In this accident, not only were employees and local residents evacuated, but many surrounding villages and towns were also shut off. It was later found out that the radioactive substances released at Chernobyl traveled on the prevailing west wind to Germany, Italy, and other nearby countries and in time to all the countries of Europe, where they spread damage by contaminating animal products.

In the JCO criticality accident of 1999, twelve years before the Fukushima nuclear accident, Japan had already experienced unexpected radiation exposure from a nuclear-power-related facility. Despite warnings of the dangers of such facilities and the systemic defects and other issues within Japan's nuclear-power regulatory administration, protective measures were insufficiently stringent, and the same mistakes were repeated. It has become clear that it is no longer possible for enterprises to cope singlehandedly with the situation of a nuclear accident or disaster, which can become an issue for the government authority that decides nuclear-power policy, or a focus of international conflict. This is thus a problem shared by the whole of humanity.

Ⅱ. JCO Criticality Accident as an Organizational Disaster

(1) JCO Criticality Accident Investigation: Non-Risk Taking

At 10:35 a.m. on September 30, 1999, during uranium fuel-production operations in the conversion-test facility of the ‘JCO Tōkai’ base at Ibaragi Prefecture, a criticality accident occurred. The criticality reaction is reported to have continued for at least 20 hours over a period of two days thereafter, during which the facility continued to emit gamma rays, neutron beams, and other forms of radioactivity. The victims of the accident were not only the workers engaged in the operation and JCO employees, but also neighboring communities. Residents living within a 350-meter radius of the site were forced to take refuge for a period of around 50 hours, and residents within a 10-km range were also obliged to remain indoors for a long period. Subsequently, chief cabinet secretary Hiromu Nonaka ordered evacuation of the area within a 30-km radius. After the accident, the number of people exposed to radiation, counting only those designated by the accident investigation committee, was 667 (initially reported as only 49). Among them was a group of three production-line operatives known as the ‘special crew’, who had been exposed to high levels of radiation, and two of whom died. Additionally, three emergency-service workers, who went to respond to the accident without being informed of its nature, were exposed to 13 mSv of radiation, while the level of exposure reached a maximum of 120 mSv among others including operatives who worked to end the criticality incident, staff at the Tōkai base, and the rescue squad. Japan’s first accident at a nuclear-power-related facility had claimed human lives and impacted communities neighboring the facility, becoming the worst organizational accident10) in Japan’s history of nuclear-power use.

In the Tōkai criticality accident, radiation ended up escaping to the exterior as there was no concrete wall to prevent it. It had been thought that criticality would be terminated immediately after an accident in nearly all cases, but in the JCO accident, where the water coolant surrounding the settlement tank served the role of a reflective material, criticality is reported to have persisted for at least 20 hours over a period of two days, as already mentioned. During this time, a major issue was the outward radiation of neutron beams, which have a strong ability to penetrate matter. When neutron beams collide with the ‘nuclei’ of the atoms making up the DNA in the body’s cells, the atomic nuclei are destroyed and the DNA is damaged. Following heavy irradiation with neutron beams, cells which have suffered fatal ‘DNA damage’ die. The operatives who were killed were treated at Tokyo University Hospital. They were unable to regenerate their skin, and died of multiple organ failure. At the request of the bereaved families, a record of their suffering was published in a book entitled *A Slow Death: 83 Days of Radiation Sickness*11).

To find out whether neutron beams have penetrated the body, measurement must be made within

15 hours. But initially, it was not recognized that the accident might involve the hazard of neutron irradiation[12)], and no neutron-beam measuring instrument was even available. The 667 people exposed to radiation included not only site operatives and staff at the JCO Tōkai base, but also local residents. The only way to measure exposure was to estimate it from a questionnaire on the activities of the radiation victims. The government maintains that, even if cancers appear in the exposed population in the future, it will not be possible to ascertain whether these resulted from the effects of the accident. However, a health survey found that 'the higher the estimated radiation dose, the greater the proportion of people complaining of symptoms[13)],' suggesting that the health damage to local residents was serious. Subsequently, JCO made a uniform compensation payment to local residents of 3 million yen each, paid during the accident investigation period, the illegality of which as 'hush money' from an enterprise to residents was pointed out. Why, in the Fukushima nuclear disaster, was JCO's experience of a criticality accident not drawn upon?

(2) *Non-crisis Management by JCO*

After the criticality accident, questions were raised about the newly revealed existence of JCO's 'secret manual', the state of its production and safety-control systems, and government safety inspections and regulatory administration, which were seen as causes of the accident or background factors. Why did the criticality accident occur not in a nuclear reactor, but in a facility for the

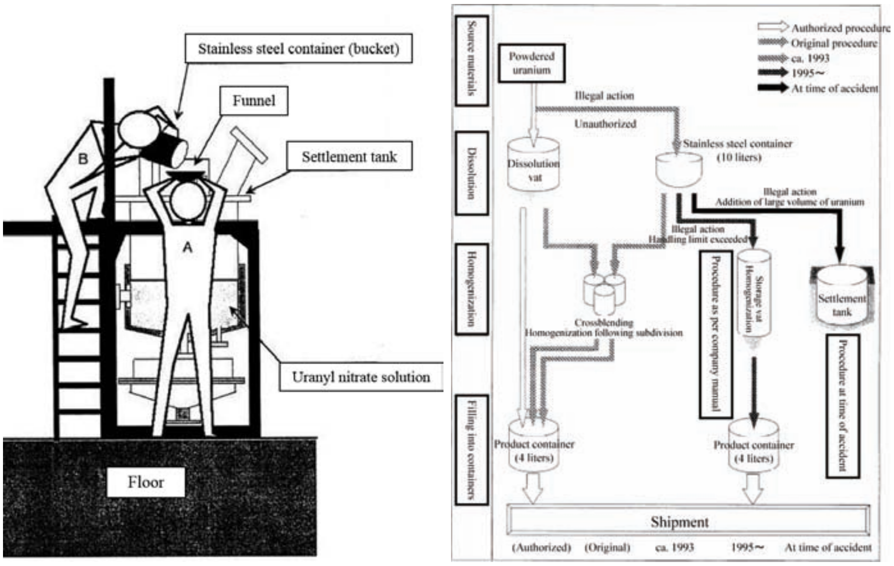

Figure 4 Operations at time of JCO criticality accident and diagram of shortcut process

Source: Nuclear Safety Commission, Report of the Uranium Processing Plant Criticality Accident Investigation Committee, 1999, Figure IV-1, Figure II-2-1.

production of nuclear fuel? Figure 4 illustrates the operations carried out by the three-person ‘special crew’ in the conversion-test facility on September 29, the day before the accident, and the operational shortcut they practiced.

As shown in Figure 4, powdered triuranium octoxide was dissolved in a special bucket and nitric acid added to create a uranyl nitrate solution. Normally, this should have been placed in a storage vat of tall and narrow shape, but before the start of operations, to ‘shorten operating’ time, the ‘labor-saving’ suggestion had been made that, instead of the time-consuming storage vat, a settlement tank should be used. This suggestion was approved by the head of the Production Planning Group, who was a qualified nuclear-fuel engineer. This change of procedure was the direct cause of the accident, but the fact that a significant change was implemented without due consideration indicates that JCO’s sense of corporate social responsibility was deficient in the area of safety and allowed risk-taking. The investigation following the accident found that this ‘illegal shortcut’ in the nuclear-fuel production process was the immediate cause of the criticality accident. The Group head who authorized the modification of the operational process for labor-saving purposes testified that ‘the shape may be different but the volume is the same, so I thought it would be alright to use the settlement tank’14), indicating misconceived notions of quality and quantity control and physical-shape regulation.

At the time of the accident, the simultaneous application of the procedural shortcut and the labor-saving technique precipitated criticality. The criticality conditions persisted for more than two days after the government’s summary statement on the accident. Because there was no neutron-beam measuring equipment available, it is still unclear when the criticality conditions were terminated. Secondary damage was therefore caused when emergency-service workers rushed to the scene after the ‘unsafe acts’15).

As it entered the 1990s, JCO began efforts to achieve more efficient operations to accompany rationalization. First came moves to abbreviate the operational processes relating to the dissolution vat. Thus, from 1993, JCO began using a ‘stainless-steel bucket’ instead of a dissolution vat and switched to on-site operations based on ‘human wave tactics’. This was not the operational method which had been authorized by government, and was in contravention of the quality- and quantity-control limit of one batch of uranium, designed to prevent criticality, which meant that a risk of criticality existed. However, because the storage vat was of the ‘regulation’ tall and narrow shape resistant to criticality, the company was blithely confident that criticality would not occur. The factors involved in the criticality accident lay not only in the on-site operations, where shortcuts were made in the nuclear-fuel production process, but extended to production control, where ‘systematic soldiering’ and ‘natural soldiering’16) combined in an organizational accident which was ‘waiting to happen’17).

(3) Systems Pathology in Japan's Nuclear Policy

What was revealed by the results of the accident investigation was that JCO had for many years neglected to carry out 'safety education relating to criticality'[18)], and that production-line operatives had almost no operational experience of the production process, which meant that the 'special crew' did not have sufficient awareness of the danger of the operation and had a low level of professional awareness as their 'career anchor'[19)]. The raw materials, equipment, procedures and other items relating to nuclear-fuel manufacture are regulated in detail by the Nuclear Reactor Regulation Law, and changes to these items naturally require a government inspection and authorization. In 1996, however, with the approval of the head of the manufacturing department, JCO produced a secret in-house manual which specified illegal operations such as the use of the special stainless-steel bucket in the dissolution process and a storage vat in the homogenization process used to create uniform concentration. JCO carried on producing nuclear fuel on the basis of this manual. In the accident, this secret manual was the basis for compounding 'organizational system error' with individual human error and for bypassing regulations on container shape by decanting the uranyl nitrate solution into the 'settlement tank', which triggered the criticality accident.

Safety inspection of JCO by the government (Science and Technology Agency) was carried out under the Basic Guidelines for Nuclear Fuel Facility Safety Inspection with reference to and in accordance with the Uranium Processing Facility Safety Inspection Guidelines. JCO was bound by the provisions of Guideline no. 12: 'Nuclear fuel facilities where there is a danger of criticality accidents caused by erroneous operation or other risk shall put in place appropriate measures for the eventuality of a criticality accident[20)].' However, the conversion-test facility was not equipped with a criticality alarm device to warn of criticality, or with a device for injecting neutron-absorbing material to terminate criticality; indeed, JCO did not even possess a neutron-beam measuring instrument. The safety inspection also overlooked the fact that the license application form contained mention neither of the homogenization process nor of the limit of one batch of uranium which supposedly applied to the processes for redissolution and homogenization. It was during this process of redissolution and homogenization, where the license conditions were vague, that the accident happened. As the Nuclear Reactor Regulation Law 'does not stipulate compulsory regular inspection' of nuclear-fuel processing facilities, there had in fact not been a single inspection by the regulatory government authority by 'security management'[21)]. Nor was there any obligation on manufacturing enterprises to report on voluntary regular inspections, and in practice the government guidance from the Science and Technology Agency, in the form of safety inspections and tours of inspection by operational-control specialists, did not constitute adequate supervision, partly because they were carried out at times when the conversion test facility was not actually in operation.

To sum up, analysis of the criticality accident shows that it was caused by a 'system error', in other words ‘organizational negligence’ in the form of procedural shortcuts based on the illegal ‘organizational secret manual’, combined with natural negligence in the form of the human error of operational labor-saving ‘self-regulation’ by systems error. The cause of the human error was a slipshod operational approach in which proper procedures were skipped because individual operatives wanted to make things easy and finish early. Questions were also raised over the fact that the special crew at the production frontline had not been informed of the risk of criticality in nuclear-fuel processing. The procedural shortcut, which had been devised to meet the irregularly placed orders for nuclear fuel supply of the ‘Monju’ Power Reactor and Nuclear Fuel Development Corporation (PNC), deviated from the standard production process and was an egregiously dangerous form of operation. The safety inspections of the government (Science and Technology Agency) were also lax and left much at the discretion of the company. This has raised questions over the ‘administrative responsibility’ of central government and the Science and Technology Agency in the field of nuclear-power policy, and has led to a rethink of the inspection standards of the regulatory authority. The background to the criticality accident was that insufficient consideration was given to internal and external ‘stakeholders’ such as the regulatory authority, employees, and local communities, and that there was also insufficient communication within the organization about hazardous operations. The ‘structural inertia’ brought about by the monopolistic nature of Japan’s ‘fuzzy nuclear-power policy’ can be identified as a kind of systems pathology.

Japan’s policy on nuclear power and related areas, as exemplified by the vague control of the nuclear-fuel manufacturing industry seen in the JCO criticality accident described above, is ‘ambiguous’. In 2014, the foreign-affairs committee of the lower house of the Diet passed a proposed treaty on the export of nuclear-power technology to Turkey, the UAE, and Vietnam under which (1) Japan would accept nuclear waste from the partner nations; (2) compensation would be provided from Japanese national taxes in the event of a nuclear accident in these nations; and (3) nuclear-power operations would also be financed by Japanese national taxes. These and other conditions, favorable only to the Japanese nuclear-power industry, are ‘unacceptable to many Japanese citizens’. Rather than learning from the experience of Fukushima and looking toward future development of ‘renewable energy sources’, Japan runs counter to the spirit of the age by seeking to export nuclear power to Turkey, a country in an earthquake zone to which even General Electric Company and Westinghouse Electric Company do not sell. This is an unsafe nuclear-power policy.

Ⅲ. Ocean Warming through Nuclear Thermal Effluent

(1) Global Stakeholders

JCO used a secret manual that ordered alteration of the procedures laid down by government safety-inspection standards to make shortcuts, and committed human error due to labor-saving of ‘administrative systems error’. In other words it committed what F. W. Taylor calls ‘systematic soldiering’ and ‘natural soldiering’, resulting in an organizational disaster in the form of a criticality accident. The issues involved in nuclear-power accidents and disasters lead us to a moral position in which all citizens of the globe are recognized as ‘various stakeholders’ (A. A. Berle)[22).

In the relationship between society and the organization, there are stakeholders such as consumers, the public and shareholders, institutional investors, suppliers, partner financial institutions, the regulatory authority, and the local community. Decision-making on organizational behavior is not possible without considering these interest groups. In contrast, JCO’s interest groups were limited exclusively to the public sector and included for instance the Science and Technology Agency, which was in charge of approval and licensing operations. No consideration was shown to plant operatives and local residents through activities such as safety and ‘information disclosure’. Specifically, local residents had not even been informed that the plant manufactured nuclear fuel. The risks from nuclear-fuel operations naturally do not only affect the employees, who are members of the organization, but are shared by members of the public and local residents. Corporate concern should not have been oriented exclusively toward business partners in the ‘uranium nuclear-fuel supply industry’ and the Science and Technology Agency, which was the regulatory authority.

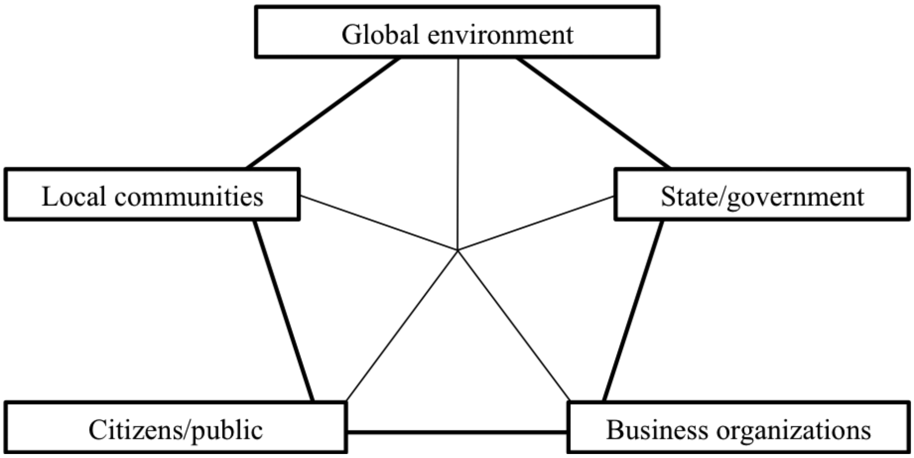

Figure 5 Global stakeholders involved in nuclear power generation

The criticality accident in nuclear-fuel-handling operations at JCO mentioned above, and the nuclear accidents at Fukushima, Chernobyl, and Three Mile Island, were not accidents limited to the locality, but disasters that grew in scale to become catastrophes that affected surrounding regions and even neighboring countries. This kind of nuclear disaster develops from an accident into a massive disaster. Thus, as shown in Figure 5, the citizens of the world have felt their impact directly at a global level as ‘global stakeholders’. For example, the radioactive substances released in the Chernobyl nuclear accident contaminated Europe’s pasturage. Among the many examples of the associated blight were cesium contamination of livestock, affecting cheese, milk, and other animal products in Germany and resulting in mass culling of contaminated rabbits in the Como region of Italy. Through food, water, and the air, radioactive contamination comes back to haunt humanity.

When accidents and disasters occur, the nuclear-power stakeholders who end up suffering the damage are residents and members of the public. The granting of rights to nuclear-power generation brought gain to some stakeholders, such as the nuclear-power industry, politicians close to the industry, and communities in the vicinity of power stations, but now, faced with the pressing issues of already-aging facilities and decommissioning, the negative side of nuclear-based electricity generation is becoming clear. A potential aspect of this is the contribution to ‘global warming’ through rising sea temperatures due to ‘thermal effluent’. Nuclear-power electricity generation requires massive volumes of water to cool down the reactors, which reach high temperatures in the nuclear-fission process. This is why nuclear power stations in all countries are located on the coast or beside large rivers. For a nuclear reactor of average size with an output of 1 million kW, approximately 70 tons of water is required every second as coolant23). The waste water is released into the sea or rivers at a temperature approximately 7°C higher than when it was taken in.

(2) The Cumulative Consequence of Effluent from Nuclear Power Stations: Ocean Warming

Currently, the major cause of global warming is said to be CO_2-based atmospheric warming. However, as the specific heat of water is much higher than that of the atmosphere, the rise in sea-surface temperature due to the continuous retention of heat energy has a greater impact on global warming than the increase in CO_2. It cannot therefore be ruled out that the cumulative effect of the human-made disaster caused by ‘nuclear thermal effluent’ is connected with natural disasters.

It is said that the rise in sea temperature—and the rise in sea-surface levels due to glacier flows which result in inflows of freshwater into the sea from the ‘Big Melt’ in the polar regions, leading to lower atmospheric pressure due to the change in specific gravity, higher levels of brackish water, and further warming—will all combine synergistically to cause sea levels to rise. At COP19, the developing countries and the developed nations were at loggerheads over the question of compensation, which the former claimed for loss of territory due to sea-level rise caused by warming (November 22, 2013). Loss of territory in low-lying countries, for instance the Maldives and Tuvalu, is indeed feared due to the effect of sea temperature on global warming and rising sea-surface.

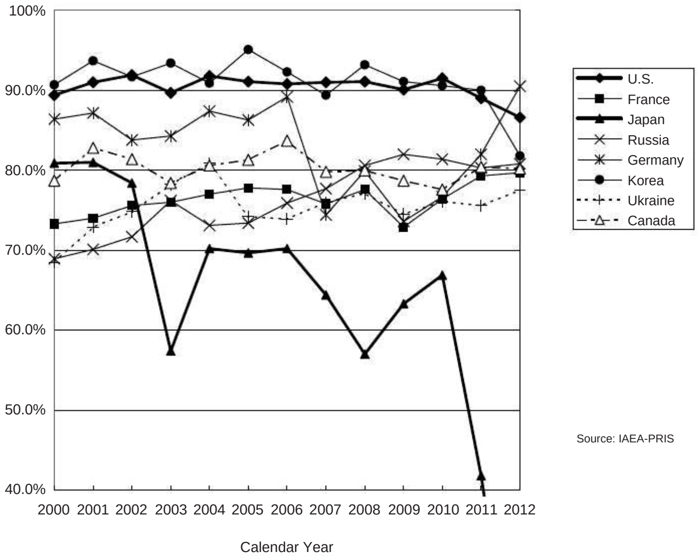

Figure 6 Capacity-utilization rates of nuclear power stations in major countries
Source: Japan Atomic Industrial Forum: Trends in Worldwide Nuclear Power Generation; 2013.

In Japan, which has 54 reactors, the world's third-highest number of nuclear power stations, according to the rough calculations of Hiroaki Koide of Kyoto University's Research Reactor Institute, every year 100 billion tons of nuclear thermal effluent is discharged, which means that a volume of water equal to one quarter of the total flow volume of Japan's rivers—that is, 400 billion tons—is released having been raised by approximately 7°C in temperature[24]. Figure 6 shows the average percentage of operating capacity used by nuclear reactors in the main countries, indicating an operating rate of at least 70 percent of capacity even as a low-end estimate after the Fukushima nuclear disaster 2011 (previously 80 percent of capacity).

Approximately 90 percent of the world's population lives in the northern hemisphere, and due to the electricity consumption that accompanies economic development, 435 of the world's 441 nuclear reactors are also located in the northern hemisphere; the total of six in the southern hemisphere consists of two each in Brazil, Argentina, and South Africa. Moreover, 39.4 percent of the northern hemisphere's surface area is land, compared to only 19.0 percent in the southern hemisphere, meaning that the land surface is relatively large and the sea surface correspondingly smaller. Figure 7 shows the northern hemisphere's 435 nuclear reactors by number of years of operation and

<table>
<tr><th rowspan="2">Area</th><th rowspan="2">Number of reactors</th><th rowspan="2">Years of Age (Avg.)</th><th rowspan="2">Total power output (Mwe)</th><th rowspan="2" colspan="2">Average power output (Mwe/reactor)</th><th colspan="4">Estimated total volume of thermal effluent</th></tr>
<tr><th>t/sec.</th><th>t/year</th><th>t/40 years</th><th>t/age</th></tr>
<tr><td>World</td><td>441</td><td>30.8†</td><td>372023†</td><td colspan="2">843.6</td><td>26,042</td><td>8.21×10^{11}</td><td>3.29×10^{13}</td><td>2.53×10^{13}</td></tr>
<tr><td>Japan</td><td>55</td><td>24.8†</td><td>47535†</td><td colspan="2">864.3</td><td>3,328</td><td>1.05×10^{11}</td><td>4.20×10^{12}</td><td>2.60×10^{12}</td></tr>
<tr><td>Northern</td><td>435</td><td>30.9†</td><td>367350†</td><td colspan="2">844.5</td><td>25,715</td><td>8.11×10^{11}</td><td>3.24×10^{13}</td><td>2.51×10^{13}</td></tr>
<tr><td>Calculation by following formula</td><td colspan="9">$70\ (\text{tons/reactor}) \times \frac{844.5\ (\text{Mwe})}{1000\ (\text{Mwe})} \approx 60\ (\text{tons/reactor})$
$V \approx 60\times864000\ (\text{sec./day}) \times 365\ (\text{day/year}) \times 31\ (\text{year}) \times 435\ (\text{reactor}) \times \frac{70}{100} \approx 1.79\times10^{13}$
$S \approx \frac{61}{100} \times \frac{1}{2} \times 4\pi \times (6.37 \times 10^{6})^{2} \approx 1.56 \times 10^{14}\text{m}^{2}$
$\frac{V}{S} \approx \frac{1.79 \times 10^{13}}{1.56 \times 10^{14}} \approx 0.115\text{m}$</td></tr>
<tr><td colspan="2">Case</td><td colspan="4">Total nuclear thermal effluent of 435 reactors in northern hemisphere</td><td colspan="4">Depth of sea surface occupied by thermal effluent (cm) = thermal effluent volume/sea surface area</td></tr>
<tr><td colspan="2">31 yrs at 70% of operating capacity</td><td colspan="4">1.79×10^{13} t</td><td colspan="4">11 cm depth (7°C rise)</td></tr>
</table>

†Average number of years of operation and total power output from World Nuclear Association, Nuclear Database 2011

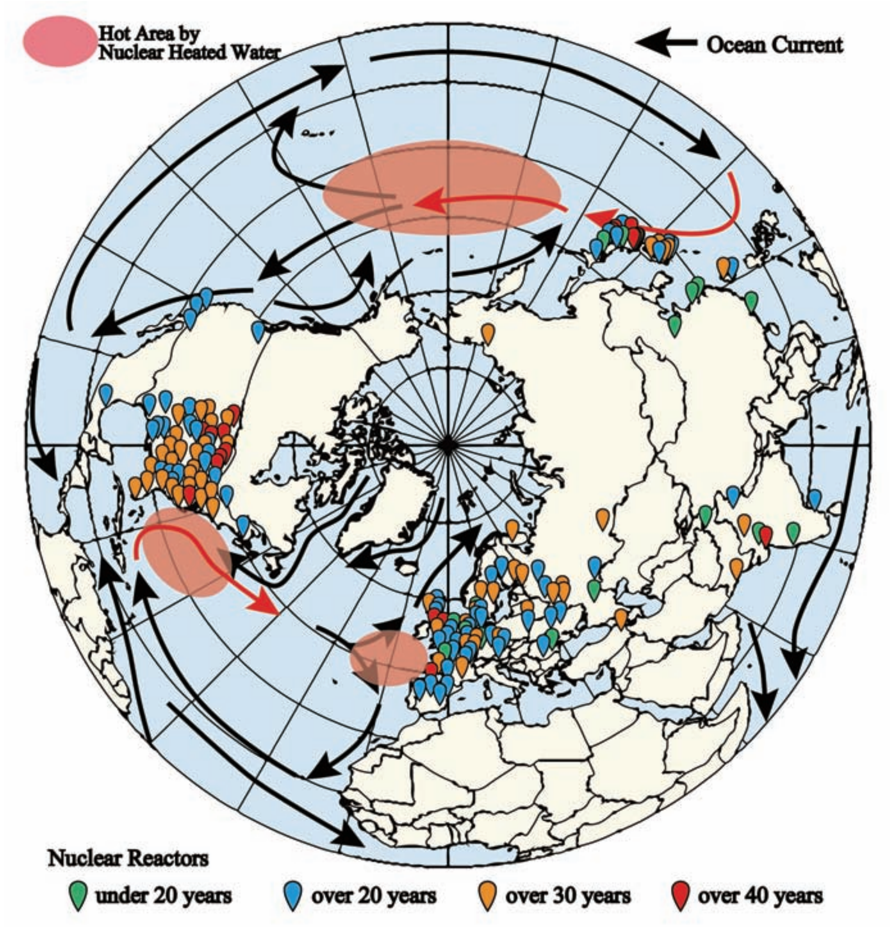

Figure 7 Northern-hemisphere sea-temperature rise caused by effluent from nuclear power stations (By S. Atsuji, K. Ueda, and R. Fujimoto.)

estimates the total volume of thermal effluent released by them, thus indicating the possibility of a ‘boiling globe’ phenomenon through overheating of seawater in the northern hemisphere. Assuming that the 435 reactors have an operating-capacity utilization rate of 70 percent, have operated for approximately 31 years, and cause a 7°C rise in 60 tons of water per second in the northern hemisphere, based on an average of 844.5 Mwe/reactor, this means that the total discharge volume of thermal effluent amounts to 17.9 trillion tons, forming a layer of approximately 11 cm on the northern hemisphere’s sea surface that consists of thermal effluent heated to 7°C above the normal sea temperature or a layer of 77 cm at 1°C above. In addition, due to convection in the atmosphere and water, temperatures are highest at the sea surface; seawater with high levels of salinity sinks, while the warming effect is greatest on the low-salinity upper layers of water, which stay on the sea surface. The greatest influence is therefore likely to be not on sea temperature as a whole but on sea-surface temperature. The sea covers approximately 70 percent of the earth’s surface, and because heat energy is more easily stored in water than in the atmosphere, it is retained for longer periods with long-lasting effects.

Ⅳ. Comparison of Ocean Overheating and CO_2 Air Warming

Figure 8 presents data on the deviation of 2013 sea-surface temperature from average values for the period 1981–2010 together with a map of the locations of nuclear power stations. As the figure shows, sea-surface temperature has risen mainly in the northern hemisphere, with a particularly high rate of rise in the North Atlantic, where there is a concentration of nuclear power stations, which may be due to the effect of thermal effluent. In a current-affairs program called *Close-up Gendai* made by the Japanese broadcaster NHK, it was suggested that the rise in sea-surface temperature shown in this figure could have repercussions as far away as Asia in the form of abnormal weather patterns and natural disasters such as floods and typhoons25). The program thus sounded the alarm over the potential threat of ‘teleconnection’.

Approximately two months after the program was broadcast, on November 8, 2013, the largest typhoon ever recorded (Typhoon 30 named *Haiyan*26)) struck the Philippines and is estimated to have claimed over 10,000 lives, constituting a major disaster of previously unknown magnitude. The U.S. Navy’s Joint Typhoon Warning Center reported it as the strongest-recorded typhoon at landfall, with maximum wind speed of 315 km/h and gusts of up to 378 km/h. Japan has also been hit by damage from unprecedented typhoons and torrential rain. In the season up to November 2013, 31 typhoons had been recorded, the first time since 1994 that the typhoon count had exceeded 30. The typhoons have also become increasingly powerful year after year, and the connection between this expanding scale and global warming has been pointed out in the Intergovernmental Panel on Climate Change

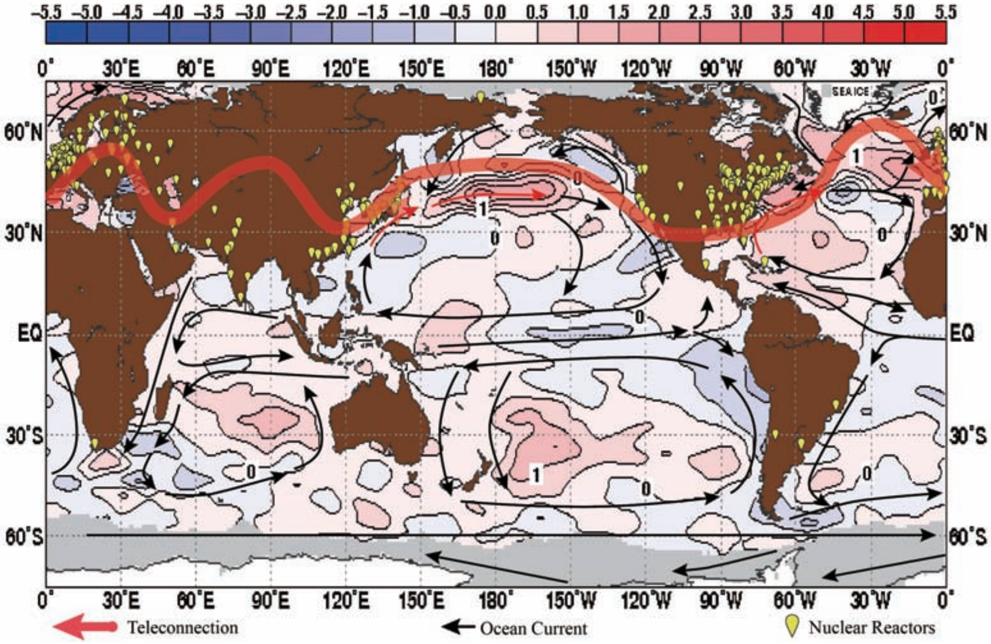

Figure 8 Climate change by nuclear-heated ocean

Source: Japan Meteorological Agency (http://www.data.jma.go.jp/kaiyou/data/db/climate/archive/b_1/glb_sst/2013/10/glb_sst.html) Accessed October, 2013. (Revised by S. Atsuji and R. Fujimoto).

(IPCC) reports[27].

In the wake of the super-typhoon that hit the Philippines (with winds averaging 324 km/h, and atmospheric pressure of 945 hectopascals), every building on the island of Leyte was left flattened, an aftermath tragically similar to that of the Japanese earthquake and tsunami disaster of March 2011. The reach of the rainstorm's winds was limited by rising land, but the formidable winds destroyed all buildings, crops, and trees on Leyte. What caused this super-typhoon of a kind never before seen in human history? It was known already in August 2013 that the surface temperature of the sea off the Philippines had risen by 2–3°C. Together with the atmospheric warming caused by CO_2 and methane emissions, sea-temperature rise is an insidious threat. Nuclear effluent directly heats the ocean, unlike CO_2 and methane which hold thermal energy.

The rise in sea temperature causes a problem of increased seawater volume leading to sea-level rise due to the melting not only of the land-based ice at the poles but also the glaciers of eastern Siberia, Greenland, the Arctic and Antarctica ice sheets, and frozen seabed. The last of these causes methane gasification and further accelerates atmospheric warming. As for the buildup of nuclear thermal effluent over the years, those who have observed nuclear-power generation and have seen the amounts of effluent involved at first hand will, like me, have been overwhelmed by its scale.

This year-on-year accumulation of nuclear thermal effluent, amounting to 17.9 trillion tons, whose temperature has been raised by 7°C in an 11-cm seawater layer (by 1°C in a 77-cm layer), cannot be ruled out as a factor in the abnormal weather patterns observed worldwide.

The IPCC also predicts a rise in atmospheric temperature of up to 4.8°C by 2100, which will be accompanied by an 82-cm rise in sea levels, while the 19th session of the Conference of the Parties to the United Nations Framework Agreement on Climate Change (COP19) in Warsaw, Poland, saw conflict as developing countries insisted that developed nations should compensate them for floods and typhoons caused by warming and for loss of submerged territory and other damage. This clash between developed and developing nations led to an impasse at the 2013 conference, which had to be extended. The extreme phenomena already being reported worldwide include unprecedented super-typhoons with air pressure under 900 hectopascals, great floods, summer snowfall in France, floods in Germany and Austria, landslides in Vietnam and Japan’s Izu Islands, and massive tornados in America. Posited as a remote cause of this is a possibility of ‘global ocean warming’ caused by effluent from nuclear power stations. If true, this demonstrates that ‘a chain of human-made disasters adds up to a natural disaster’, and that ultimately the two types of disaster are intertwined via teleconnection.

In a project to predict the situation with global warming around the end of the 21st century, conducted by research groups including the Meteorological Research Institute of the Japan Meteorological Agency and the Advanced Earth Science and Technology Organization28), it is stated that the number of very strong tropical low-pressure systems with maximum wind speeds over sea or land of more than 162 km/h is on a rising trend due to the increasing scale worldwide of typhoons, hurricanes. and cyclones, with a rise in sea level caused by extremely low air pressure like the 895 hectopascals of the Haiyan super typhoon of 2013, and other weather events accompanying global warming. If human activity, including such thermal effluent, is promoting global warming, then there is, underlying natural disasters such as typhoons and torrential rain, floods and earthquakes, an accumulation of human-made disasters. As with the Fukushima nuclear disaster, which arose out of the Great East Japan Earthquake, there are cases where natural disasters develop into human-made disasters; but conversely, there are also cases where natural disasters develop out of unnatural disasters. The cumulative chain of human cooperation thus creates a situation where ‘human-made disasters and natural disasters are interconnected’, and contributes to the un-safety.

Even more so than the global warming caused by the protected thermal energy of the globe by CO_2 and methane, the ‘boiling globe’ effect of the total thermal energy of the globe by heated water has the potential to produce ‘unexpected consequences’. For instance, the permanently frozen glaciers of Greenland and Antarctica could melt under the influence of global warming and form a moraine. The moraine would cause water to flow in and gather two to three kilometers below the ice sheet, which would lift the glacier so that the whole ice cap might plunge into the sea in one piece, setting off a huge wave. As the ice cap lifted with further melting, the rising sea-levels of the continents of Greenland, Siberia, the Arctic and Antarctica, which had until then been subject to subsidence of several kilometers, might suddenly be forced upward and release a tsunami. In such an event, there would be a threat of un-safety to the coastlines of countries around the North Sea, such as Norway, Iceland, and Great Britain.

The nuclear accidents and the possibility of warming caused by thermal effluent accumulation, which are presented here as examples, point precisely to the ‘interconnection of human-related natural disasters’. This highlights further aspects of the multiple impacts of nuclear power on the environment, including atmospheric and marine pollution in the event of an accident, and thermal effluent. The impact on the environment means direct impact on the ecosystem and people living in the environment. Going forward, in response to the danger which has passed the limits of manageability by businesses and central governments, there is a need for a preventive social function to oppose the collusive relationship between business management and government policy over nuclear power. Essential here is a global eco-civilization in which individual citizenship has preventive power.

Acknowledgment

Grateful thanks to Prof. Kōichirō Hioki (Kyoto University) and Prof. Nobuaki Yoshida (Kansai University)

This work was supported by MEXT KAKENHI Grant Number 24530437

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