



Coping with Unexpected Incidents through Environmental Resilience to Promote Human Adaptation

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Authors' contributions

*Author MY designed the study, wrote the protocol, and wrote the first draft of the manuscript.
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ABSTRACT

When the Great East Japan Earthquake struck on March 11, 2011, a large number of people and organizations faced unexpected situations. Even under such circumstances, some people flexibly responded to the situation to minimize damage caused by the disaster beyond the codes of conduct, including manuals, laws, regulations, precedents, and procedures learned in training, that should otherwise have been complied with. Although some of them ended in failure, most yielded positive results for the following reasons: 1) the possibility of accidents was considered even before the earthquake to prevent them as much as possible; 2) when the unexpected occurred, people on the front line of the disaster voluntarily and autonomously made decisions and acted. It was suggested that, in the event of such a disaster as the earthquake in Tohoku, adaptation and resilience are required to respond to the situation, rather than relying on manuals. As a key point, it is important to enhance the abilities of individual persons and evaluate their efforts in each situation to improve the resilience of individuals and organizations, instead of assessing their approaches solely based on the results.

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1. INTRODUCTION

Three disasters at nuclear power plants: on Three Mile Island, in Chernobyl (1986), and Fukushima (2011), have shocked the world and actually had significant impacts on the global environment [1-3]. When the most recent occurred in Fukushima, the word "unexpected" was frequently used by staff of Tokyo Electric Power Company and specialists in nuclear power engineering. Similar unexpected catastrophes occurred two times involving space shuttles during a short period of time - rockets for shuttle flights between the earth and space developed by the U.S. with particular emphasis on their safety, although the risk of an accident was estimated to be very low [4-6].

Had the possibilities of these accidents been seriously discussed before they actually occurred? Were they literally unexpected accidents? Or, did people use the term "unexpected" to protect themselves while actually expecting them to occur? Looking back on these accidents, a large number of people might have expected them to occur in the near future without confidence, although few are considered to have accurately predicted the timing and scale and become seriously concerned.

Besides the above-mentioned examples, the term "unexpected" is used in a significant number of cases around the world [7-11]. Efforts to prevent such accidents have been made and questions have been asked for decades - "Why do accidents occur?" and "What is safety?" However, previous risk predictions of accidents were based on examples that had occurred in the past while focusing on the classification of errors and calculation of the probability of accidents, and examples of accidents were added on an as-required basis [12-14]. In other words, these are hindsight-based or reactive approaches. Environmental issues, including chlorofluorocarbon and endocrine-disrupting chemicals, which have long been forgotten by most people, are examined using similar approaches.

However, in recent years, completely new methodologies, instead of conventional research methods, have been used to conduct research on safety. These methodologies focus on resilience, or the ability to predict the risk of an accident or damage before it occurs by identifying changes in risk factors, to discuss safety - and foresight-based or proactive approaches [15]. Resilience, a common concept in ecology and other fields, is the ability to cope with a marked environmental change, adapt to it, and recover from temporary dysfunction [16,17]. Based on this idea, the present paper discusses the importance of "environmental resilience" - a new concept to reduce accidents and their influences. Global warming, biodiversity loss, damage to sustainability, and a decrease in marine resources may also be regarded as unexpected events, as all these problems occur as results of the interaction between humans' economic activities and the global environment. Environmental resilience is expected to contribute to solving these problems.

So far, previous studies yielded the following two findings regarding accidents [14]:

Firstly, an accident occurs under multiple, unexpected, adverse conditions, not because of simple dysfunction or damaged equipment.

Secondly, as accidents and safety are inextricably associated with each other, no specific mechanism is required to explain an accident.

Both an accident and safety have their roots at the level of individuals, organizations, or systems. For example, safety is ensured when multiple events occur while affecting each other in a positive manner. People tend to assume that safety is ensured by skillfulness and sophisticated systems, and that an accident is caused by errors, carelessness, or poor systems. However, these are only partially correct.

You do not have to look back on the March 2011 accident at the TEPCO Fukushima Daiichi Nuclear Power Plant in Japan to understand the importance of the safety of large-scale technical systems. However, ensuring the safety of such systems is also essential to protect environments for people around the world. Nevertheless, it has become increasingly difficult to create a safe society in Japan and other countries. This is because, in recent years, the majority of people think that, as long as you comply with instructions written in manuals, nothing can go wrong, or at least you will not be held responsible even if problems occur. In other words, most people act solely for self-protection. Since the Great East Japan Earthquake followed by the accident at the Fukushima Daiichi Nuclear Power Plant, this tendency has become more notable and it has become even more difficult to ensure safety, and, as a result, some people have started to think that accidents cannot be prevented. However, accidents should be prevented, if possible. People have long believed that the best way to prevent accidents is to improve or enhance systems and equipment as much as possible and encourage people to learn high-level skills.

However, nowadays, there are suggestions that these measures may be inadequate and cannot completely prevent accidents, and a completely different approach should be developed. The concept of resilience has been receiving attention. The term "resilience" has many different meanings depending on the field in which it is used. In the present study, the term refers to "a person's adaptability to circumstances and situations through knowledge and experiences" - "environmental resilience". Although some may doubt its potential: "What can a person's adaptability do?" "Can it prevent accidents?", the abilities of humans are considered to serve as the last defense against a serious accident in places such as nuclear power plants equipped with large-scale facilities [14]. Although there is a proverb: "To err is human, to forgive divine", we still hope that our abilities play a role in preventing accidents.

2. WHAT IS ENVIRONMENTAL RESILIENCE?

Dictionaries contain two basic definitions of resilience: "the ability of an object to resume its original shape when it has been under external pressure" and "a person's ability to recover from difficulty". The term also has derivative meanings: "the essential ability to control system functions before, during, or after they are affected by changes or external factors" or "continue required operations under both expected and unexpected conditions" [18-20]. According to Woods et al., a scale to determine resilience is insight or an ability to foresee accidents and damage by identifying altered forms of risk [21]. It is the ability of persons to predict and promptly and appropriately respond to, for example, any environmental changes and risks posed to all organisms on the earth. This ability can be regarded as the "ability to assume" or "capacity for tactfulness". Some researchers are seeking ways to encourage people to enhance resilience, in particular, and help organizations facing unusual conditions reduce or avoid risks in a secure and flexible manner to prevent accidents or reduce damage [22]. This approach, classified into a method of resilience engineering in recent years, aims to help technologies, systems, and organizations that contribute to society continue to safely operate [7]. It prevents small-scale incidents or changes in situations from developing into serious accidents. It does not view humans as a factor threatening the safety of systems, but

as masters who safely operate or cope with those systems associated with inherent risks while taking into account efficiency, productivity, and cost reduction [23].

However, more efforts are required. It is essential for people to develop their abilities to flexibly respond to unexpected events and minimize damage. Of course, it is also important to maintain the condition of a system at the highest level to prevent accidents. Nevertheless, unexpected events will occur in society. People have only limited knowledge even of expected accidents. If a person can flexibly address an unexpected accident, instead of not knowing what to do and wasting time, it will significantly reduce damage. On assessing responses to and the handling of an accident, it is more important to assess the early detection of changes in the situation and prevention of errors due to resourcefulness and analyze how they contributed to the prevention of a second disaster, than examine human errors as the causes of the accident.

Changes in the situation are both expected and unexpected. Therefore, the fact that a serious accident did not occur suggests that people were able to continue their activities while appropriately coping with a significant change. This is considered to be safety. In summary, safety refers to the control of a system in the event of a (possible) change. Therefore, safety is not necessarily the result of careful planning.

An order in a social system is usually formed through a legal system established by a law-abiding country based on a top-down approach. However, as modern social systems have become more complex, it is necessary to review the top-down method for order formation to respond to unexpected events more flexibly.

It is necessary to develop a bottom-up method to train people who can flexibly adapt themselves to changes in the situation, based on the recognition that only concerned persons have the knowledge required to solve problems.

3. THE POSITIVE EFFECTS OF PEOPLE'S ADAPTABILITY

3.1 The Case of Japanese Red Cross Ishinomaki Hospital

Two examples from the Great East Japan Earthquake can be used to explain the situation. The first one involves Japanese Red Cross Ishinomaki Hospital [24]. When the Great East Japan Earthquake struck, very few hospitals immediately established a critical care system, similar to that of a field hospital, to accept a significant number of emergency patients [25]. One of them was Japanese Red Cross Ishinomaki Hospital.

Although the hospital is in Ishinomaki, a city severely damaged by the earthquake and tsunami, the region in which it is located was spared from the tsunami, and only minimal damage was caused by the earthquake since most buildings were seismically isolated. The power, water, and gas were cut off, although electricity was soon restored with isolated power units. Not only the injured but also community residents gathered around the hospital since it was the only brightly lit place, thanks to in-house power generation, in the dark city.

Immediately after the earthquake, the hospital cancelled its normal outpatient services and performed triage to maximize life-saving, as hospital staff had undergone training on a regular basis [26]. They prepared themselves to provide care for patients affected by the earthquake. However, the following day, modifications were added to the system to treat

hypothermia patients affected by the tsunami. As members of the Disaster Medical Assistance Team (DMAT) arrived at the site, with one group after another, hospital staff were able to share roles with them in a flexible manner. Although there were severe shortages of drugs, water, and food as an increasing number of patients arrived over time, hospital staff continued to provide medical services according to self-imposed rules while collaborating with external staff in the difficult situation. A few days later, on March 17, the hospital started to dispatch its staff to about 300 evacuation centers in surrounding areas to examine their conditions. Considering that simply waiting for patients was inadequate and too passive, the hospital stepped up efforts to collect information. Hospital staff recognized that not only medical care but also sufficient food and appropriate hygienic environments were needed, and negotiated with the Ishinomaki city and Miyagi prefectural governments, beyond the framework of a health care institution, to request measures to address these needs. One month after this, the hospital resumed outpatient services, after going through a number of hardships.

Under the theme of "Only humans can save humans", which is also the slogan for The Japanese Red Cross Society, all 873 staff worked around the clock. This is a good example of a resilient system: environmental changes - continuation of actions to adapt to the changes - avoidance of catastrophic situations - modifications added to the objectives of activities in an active manner for adaptation.

As another example, teachers and students of a junior high school survived after moving from a designated evacuation center, which they thought was not completely safe, to a higher place. On the other hand, a large number of lives were lost in an elementary school because it only emphasized emergency manuals and failed to flexibly respond to the disaster; the school was hit by the tsunami when teachers were lining their students up for a roll call before evacuating. The following are examples of favorable results: a convenience store provided affected people with products, including bottles of water and food, free of charge, without receiving permission from the headquarters; a restaurant served people who had to walk home with no transportation with hot drinks.

A more resilient society can be created by helping people develop knowledge and creativity so that they will be able to use them in the event of an unexpected accident. Of course, new problems may occur when people become involved in a system. This is because it is difficult for people with different subjective views to accurately assess the sense of fear caused by environmental changes. Nevertheless, it is essential to enhance people's knowledge and creativity.

In the following examples, people failed to respond flexibly: some local governments accepted relief supplies sent from all regions of Japan but did not distribute them to affected people, simply because local governments in the disaster-stricken areas did not ask them to do so; some health care institutions refused to share medical drugs required for emergency treatment with other hospitals, citing the Pharmaceutical Law as the reason. In these cases, more damage was caused or support activities were interrupted by people who did nothing other than comply with laws, manuals, and precedents, or acted exactly as taught or trained. Unfortunately, the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant occurred due to a lack of resilience [27].

3.2 The Case of Passengers on Trains at the Time of the Tsunami

The second example involves JR East (Japan Railroad East) [28]. Immediately after the Great East Japan Earthquake on March 11, 2011, there were reports on derailments of one Shinkansen bullet (out of service) and four local trains (in service) on the JR East line. Passengers of at least 27 trains evacuated and five trains were swept away by the tsunami. Surprisingly, all passengers were safe.

Although the control center of JR East was responsible for issuing evacuation directives, some trains could not receive them because radio transmission had been disrupted due to the earthquake. However, when trains were parked at a relatively low elevation near the coast, all people were able to evacuate to a higher place or evacuation area in a calm way, which was based on the crew's decisions and passengers' opinions. On the other hand, when a train was parked in a relatively safe place at a high elevation, passengers and crew decided to stay on the train to protect themselves from cold, and all of them survived.

In the news paper article on April 10, 2011 [29]:

Immediately after the Great East Japan Earthquake struck, a train parked at JR Shinchi Station in Shinchi-machi, Fukushima Prefecture, was engulfed by the massive tsunami. Two policepersons who happened to be on the train saved the lives of about 40 passengers and crew. The policepersons said that they had been driven by the lesson: "Even when policepersons are off duty, their hearts must be in uniform", taught by the police school.

The two officers, on their way to the Soma Police Station from a police school in Fukushima City, were actually wearing business suits on that day.

When the train was jolted by the earthquake, there were approximately 40 passengers in their 20s to 70s. According to one police officer, "they were shocked at the jolt". He saw a massive tsunami warning on the display of a mobile phone held by a passenger.

The other policeperson showed his ID to the crew to prove that they were police officers, and they spoke to all passengers: "Let us all evacuate to the town office". For a moment, they thought, "What if there is no tsunami and the evacuation turns out to be unnecessary?" Nevertheless, they opened every door by hand, so that passengers would not be trapped in the cars if they were damaged by the aftershock, and evacuated all people to the town office, located on a hill approximately one kilometer into a mountainous area. Although an elderly female refused to evacuate, saying: "I am all right and will stay here at this station, waiting for my family", one of the officers patiently persuaded her to come along with them.

When the police officers arrived at the town office on the hill and turned around, "they saw giant waves engulfing automobiles and buildings, and were shocked at the sight". The passengers, although most of them had been doubtful, became pale and screamed.

4. DISCUSSION

Conventionally, safety improvement aims to prevent situations from becoming worse. This is based on the notion that all accidents or incidents have unique, identifiable causes, which can be resolved or reduced. In other words, it is believed that safety can be improved by eliminating causes of undesirable situations. The notion is based on the idea that the causes

of undesirable events, or accidents, are different from reasons or grounds for safety. Otherwise, the notion would not be theoretically grounded because "Elimination of a cause of an accident reduces safety".

On the other hand, the concept of environmental resilience suggests that an accident and its related safety share the same cause. When an event occurs, it has specific causes and develops into an accident or other incidents. Therefore, desirable and undesirable results share the same causes.

Safety is regarded as a situation or characteristic, and the term is often used in expressions, such as "The safety of the operation is marked". The concept of environmental resilience rather suggests that "safety is created". Safety is not "something" included in a system, it is something accomplished by the system. Therefore, assessment of safety should not be conducted solely based on the results, or the number of accidents. It should be performed based on the process of implementing an operation.

In recent years, when an accident occurs, the importance of the development and modification of procedure manuals, as well as their compliance, is suggested as effective measures. However, safety cannot be ensured solely by complying with manuals. As the negative side of this, people at work sites only focus on following manuals and stop thinking. Furthermore, people will tend to think that they will never be responsible for accidents as individual persons or lose their jobs as long as they comply with manuals. They will eventually stop following procedural manuals for accident prevention, and become unable to think of effective methods to address unexpected accidents.

On May 25, 2013, there was a short news article on a radiation leak at an experimental nuclear energy facility in Ibaraki Prefecture, Japan, under the headline: "On the night of the 26th, 30 people exposed to radiation of 1.7 mSv, Experiment reset and resumed". However, when the accident occurred, it was not reported immediately but actually concealed [30]. At that time, researchers turned on the fan and let out the radiation-contaminated air, as if they were preschoolers. They did not even think of the consequences. What is even worse, they attempted to cover up the accident. This may reflect the essence of modern people who have little knowledge outside their own specialized fields or no broad vision.

5. CONCLUSION

In this paper, it was suggested that, in the event of such a disaster as the Great East Japan Earthquake struck on March 11, 2011, adaptation and resilience are required to respond to the situation, rather than relying on manuals. As a key point, it is important to enhance the abilities of individual persons and evaluate their efforts in each situation to improve the resilience of individuals and organizations, instead of assessing their approaches solely based on the results.

In this era, people are required to improve their basic abilities to always view things from a broad perspective and comprehensive point of view, even in emergency situations, and flexibly and effectively cope with an accident or disaster to overcome it and reduce the resulting damage as much as possible. Otherwise, accidents cannot be prevented.

These predictors, however, need further work to validate reliability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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