Chapter 5
Disasters and Their Impacts on Air Quality in the Human Living Environment

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Abstract Although clean air is one of the most important necessities for human life and health, the risk of natural disasters causing air pollution that reduces or inhibits "resiliency" of the victims and communities has not been well understood. This chapter examines the secondary disaster of the air pollution events induced by the Great East Japan Earthquake and subsequent tsunami in 2011—such as the release and diffusion of radioactive substances from the severely damaged Fukushima Daiichi nuclear power plant, chemical contamination in indoor air of temporary housing built (so-called Sick House Syndrome), and the scattering of asbestos fibers liberated by the quake and tsunami. Air pollution is something that often cannot be seen until severe impacts are noticed later. The paper then describes the importance of air quality monitoring by scientific means and sharing knowledge for risk recognition and immediate pollution controls based on the identification of source of problems for risk reduction, in the context of resilience.

Introduction

In assessments of human well-being, poor air quality is one of the typical kinds or causes of human insecurity, but people often pay little or no attention to the deteriorating quality of air until it begins to harm their health, erode ecological systems, or generates unexpected impacts on the global climate (Wang and Sekine 2009). Natural disasters may cause significant physical destruction, loss of life and property, and drastic changes to the environment. Some disasters, such as forest fires and volcanic eruptions, become a source of air pollution, which increases the

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risk of respiratory and heart disease in the population, by emitting large amounts of gases and particles into the atmosphere (Brimblecombe 1996). Meanwhile, little is known about the *secondary disasters* of air pollution induced by natural events such as earthquakes, floods, tsunamis, landslides, hurricanes, and so on. Since secondary air pollution is not a direct result of a disaster (it is often man-made) and sometimes occurs in indoor environments, it often merely becomes a popular topic of discussion. However, in previous instances disaster victims or their communities have suffered from health problems caused by disaster-induced air pollution in the human living environment. Examples include the chemical intolerance of hurricane and earthquake victims living in temporary housing (Tang et al. 2009) and latent illness caused by past exposure to asbestos (Mainichi Shimbun 2012).

On March 11, 2011, the Great East Japan Earthquake and subsequent tsunami devastated the northeastern coast of Japan. The tsunami swept away most coastal towns and cities in the region, destroying many buildings and much infrastructure, and severely damaging the Fukushima Daiichi nuclear power plant, which led to the release of radioactive substances into the environment. While this natural disaster caused catastrophic environmental degradation in many ways, this study focuses on secondary air pollution problems that threaten human comfort and health, namely the diffusion of radioactive substances, chemical contamination in temporary housing, and the scattering of asbestos. Figure 5.1 illustrates major and possible human health concerns related to air pollution problems induced by the 2011 earthquake.

In this chapter, we attempt to identify the vulnerability of air quality in the human living environment, in the context of the 2011 disaster, and discuss the importance of monitoring air quality in order to recognize risks in terms of resilience.

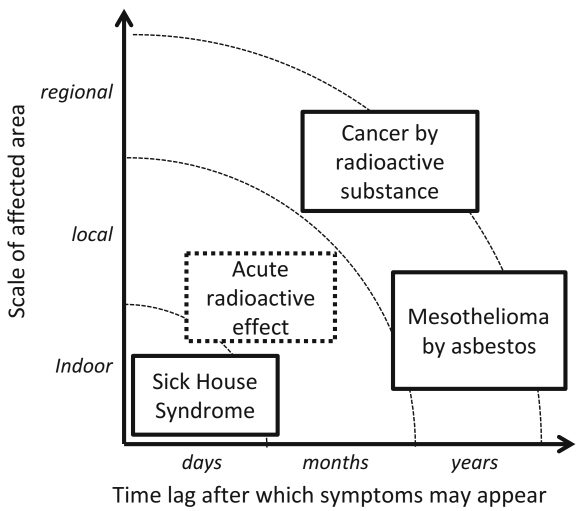

Fig. 5.1 Conceptual image of the potential health problems related to air pollution induced by the Great East Japan Earthquake. The issues are categorized by both the scale of the affected area and the time lag after which symptoms may appear after significant exposure to each air pollutant

Diffusion of Radioactive Substances

The Fukushima Daiichi nuclear accident consisted of a series of power failures beginning on 11 March 2011, nuclear meltdowns, and releases of radioactive substances at the nuclear power plant. It is the largest nuclear accident since the 1986 Chernobyl nuclear accident and has to date been classified as a Level 7 event (major accident) on the International Nuclear Event Scale. On March 14, a total of 77,000 residents were evacuated from ten towns and villages within 20 km (kilometers) of the power plant, and people living within 20–30 km of the site were urged to stay indoors because of leakage of radioactive substances into the atmosphere from the containment unit damaged by hydrogen explosions at the plant. While the release of radioactivity to the environment is of concern, owing to the potential acute and long-term health effects, radiation levels in the atmosphere indicated the long-range transport of radioactive nuclei even in the Kanto region (in the eastern half of Japan, which includes Tokyo and Kanagawa Prefecture). However, the number of radiation monitoring sites was not sufficient to properly ascertain the distribution of radioactivity both in time and space. Insufficient information aroused a feeling of fear among citizens about the accident, and the public's general lack of scientific literacy on radiochemistry spurred further confusion. Some people voluntarily evacuated from the Kanto region to the western part of Japan, while some foreign students and residents decided to leave the country.

During this time, the authors were carrying out regular sampling of airborne particulate matter at Hiratsuka, in the prefecture of Kanagawa, approximately 260 km from the damaged plant, for the observation of yellow sand carried by air flow from the Asian continent. Aware of the possibility of the transport of radioactive substances from the plant, we then began immediate measurements of radioactivity of the collected particulate matter. Our findings included the presence of radioactive cesium (134-Cs, 137-Cs), iodine (131-I, 132-I), and tellurium (132-Te), which are relatively volatile nuclei typically produced by nuclear reactions involving uranium, and were likely released from the plant (Ikeda and Sekine 2012). These findings suggested that the deposition of radioactive nuclei onto the ground may have produced "radiation hot spots," or sites specifically contaminated by radioactive substances, even in the Kanto region. This situation was soon proven by the detection of high levels of radiation in agricultural products and radiation monitoring by the government, conducted by aircraft, in September 2011 (MEXT 2011). Our detailed investigations also showed that the radioactive substances were transported by air in the form of fine particles with a diameter of approximately 1 μm (micrometer) (Ikeda and Sekine 2012). Such fine particles, when inhaled, can be deposited in airways or lungs. Long-term exposure to these radioactive fine particles may increase the incidence of adverse health effects such as thyroid cancer and leukemia. This information was shared with the scientific community to encourage the evaluation of risk to humans.

After the major release of radioactive materials on March 15 and 16, 2011, the leakage of these materials from the damaged plant decreased due to the great efforts of plant workers and luck. Based on monitoring and epidemiological data, a World Health Organization (WHO) report in 2013 concluded that the predicted risks were low and no observable increases in the occurrence of cancer above baseline rates were anticipated for the general population inside or outside of Japan (WHO 2013). However, even at the controlled level, many people in Fukushima and the surrounding area are still being exposed to radiation at present. It is coming from the soil, plants, and pavement contaminated through air pollution. Since there is still existing uncertainty on the health effect of exposure to low levels of radiation for decades, especially on babies and children, the victims are forced to be in invisible, unexpected, and latent fear of the radioactivity. It is essential to remove the radioactive substances from the living environment in order to promote the "resiliency" of the victims and their communities.

Indoor Air Pollution Caused by Chemicals in Temporary Housing

Many people who lost their homes due to the earthquake and tsunami, or who lived within a 20 km radius of the plant, were forced to evacuate to temporary housing areas. More than 54,000 temporary houses have been built since the disaster in the prefectures of Miyagi (22,000), Fukushima (18,000), Iwate (14,000), and others (METI 2012). Related to this housing, it is important to be aware of the indoor air quality of the newly-built temporary houses. Studies have described the problem of secondary air pollution caused by harmful chemicals that produce the so-called "sick house syndrome" (SHS). For instance, when Hurricane Katrina struck the Gulf Coast of the United States in 2005, victims were temporarily housed in trailers provided by the government. The trailer residents soon reported sinus infections, respiratory problems, and a burning sensation in the eyes, due to exposure to dangerous levels of formaldehyde gas in the indoor air (Parthasarathy et al. 2011; Maddalena et al. 2009; Madrid et al. 2008). After the 2008 earthquake in Sichuan, China, many survivors, including expectant mothers, moved to into temporary mobile homes. Though the Sichuan government explicitly prohibited media organizations from reporting, more than 100 miscarriages by women were found in the community, probably because of exposure to high concentrations of formaldehyde emitted from interior materials (New York Times 2009).

Ordinarily, indoor air quality in newly built permanent dwellings is regulated in Japan by guidelines for indoor air concentrations of volatile hazardous chemicals and by building codes that mandate ventilation and emission rates of formaldehyde from building materials. Temporary housing, however, is exempted from Japan's building code. Furthermore, house builders may have felt compelled to use interior building materials without considering emissions of volatile hazardous chemicals, due to shortages of proper materials to construct the large quantities of temporary housing required to meet the immediate and simultaneous demand for housing of disaster victims. Knowing these circumstances, researchers in the field of indoor environments became concerned about the health effects of poor indoor air quality in the newly built temporary dwellings.

Miyagi prefecture required builders to report indoor air concentrations of only five specific chemicals (formaldehyde, toluene, xylene, ethylbenzene, and styrene), and testing was only required for one house per construction order (typically 50–60 houses). The five chemicals were subject to the Housing Quality Assurance Act in 2002 and the Standard of School Environmental Sanitation in 2004. Some experts, however, call for more detailed and extensive testing in order to prevent indoor air pollution problems, because chemicals other than the five compounds are known to have caused health disorders in recent cases (Kobayashi et al. 2010). Subsequently, the authors urgently conducted a field survey on the indoor air concentrations of chemicals at five houses in one temporary housing area in Miyagi in June 2011, with the cooperation of the Miyagi prefectural government (Oikawa et al. 2011). The target substances were three carbonyl compounds, 43 volatile organic compounds, and total volatile organic compounds (TVOC). The results showed that the indoor air concentrations of chemicals whose indoor air guidelines were previously set were below the guideline levels at all sampling sites. However, TVOC concentrations ranged from 1,700 to 3,000 μg per cubic meter (m^3), 4–7.5 times higher than the tentative guideline for TVOCs. Chemicals not regulated by the governmental countermeasures contributed to such extraordinarily high concentrations of TVOCs in the temporary houses surveyed. The results were soon announced on the website of the Society of Indoor Environment, Japan (SIEJ), for the reference of indoor air quality of temporary houses under construction. A broader and more exhaustive survey was conducted separately at 19 newly-built temporary houses in Minamisoma City, Fukushima Prefecture, from August 2011 to January 2012 (Shinohara et al. 2013). The mean air changes per hour in the temporary houses were 0.28, and no 24 h ventilation systems were installed. To an expert, these facts suggest the houses are air-tight compared with ordinary houses (the Japanese standard requires 50% air change of a house every hour) and can potentially lead to severe indoor air pollution when stand-alone combustion heaters are used in winter. Meanwhile, indoor concentrations of volatile organic chemicals other than acetaldehyde and TVOCs did not exceed the indoor guidelines even in the air-tight houses. Although there was a report on suspected sick-house syndrome incidents (Jiji Press 2011), the secondary disaster of indoor chemicals in temporary houses has not been remarkable, probably because of careful use of building materials and monitoring by both the government and voluntary research groups.

Incidentally, the survey in Minamisoma also showed that the shielding effect from radiation was less in temporary houses than in reinforced concrete or steel-framed buildings (Shinohara et al. 2013). The air-tight temporary houses were good at preventing the penetration of airborne particulate matter or dust, even when the air was contaminated by radioactive substances, but radiation from radioactive substances may pass through the walls of the houses. These findings suggest that the shielding effect of the buildings' roof and walls should also be considered as an important item for the further improvement of specifications of temporary houses in order to reduce cancer risk caused by radiation when will be built in the contaminated sites.

Asbestos, A Time Bomb

Meanwhile, the Great Hanshin-Awaji Earthquake in 1995 destroyed many buildings containing asbestos, a long, thin fibrous crystal of silicate minerals used for thermal or sound insulation and fire-proofing. In 2011, 16 years after that quake, a man who had worked disposing of earthquake debris died from mesothelioma, probably due to past inhalation or ingestion of asbestos fibers liberated by the quake (Mainichi Shimbun 2012). It is predicted that the number of victims will increase in the near future, because symptoms often do not appear until decades after exposure to asbestos. A similar situation can be predicted for the 2011 earthquake and tsunami case, from which disaster-related wastes are being collected at temporary waste storage sites in great amounts. The asbestos-containing wastes, as well as other hazardous wastes, are being separated from other waste and disposed according to their properties, in accordance with the "Guidelines for Disaster Waste Management after the Great East Japan Earthquake" by Japan's Ministry of Environment. Past experience has shown that it is essential to control the exposure of workers to airborne asbestos in order to reduce the risk of mesothelioma throughout the treatment process. The failure to do so can turn inhaled asbestos into the equivalent of a time bomb.

Conclusion

Natural disasters may well be unavoidable by human intervention, but secondary disasters that reduce or inhibit the "resiliency" of the victims and their communities could be better managed by identifying the sources of problems. As mentioned above, the Great East Japan Earthquake induced serious air pollution problems in the human living environment. Air pollution is something that often cannot be seen until severe impacts are noticed later. Air quality monitoring by scientific means is therefore essential in order to minimize environmental health risks. In addition, measurement systems or tools should be made more easily accessible for non-professionals so that anyone can ascertain the status of personal air quality in an emergency, with a special priority for children, the elderly, and the poor, and people who are already ill, as these groups are more susceptible than the general population to the risks of air pollution.

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