

Chemical Contamination, Cleanup and Longterm Consequences of Japan's Earthquake and Tsunami 日本の地震と津波、化学汚染・除染・長期的結果

Winifred Bird, Elizabeth Grossman

Chemical Contamination, Cleanup and Longterm Consequences of Japan's Earthquake and Tsunami

Winifred A. Bird and Elizabeth Grossman

Writers Winifred A. Bird and Elizabeth Grossman followed the unfolding Tohoku disaster from their respective offices in Nagano, Japan, and Portland, Oregon. To form a picture of the damage, begin to understand how chemical contaminants and their potential health hazards are being handled after the tsunami, and assess their longterm effects, Bird visited the hard-hit prefectures of Ibaraki, Iwate, and Miyagi, while Grossman researched company and chemical information and how such issues are handled in the United States. While Japanese and international attention has focused on radiation danger associated with the meltdown at the Fukushima Daiichi reactors, chemical contamination also promises to significantly impact the region and its ability to recover.

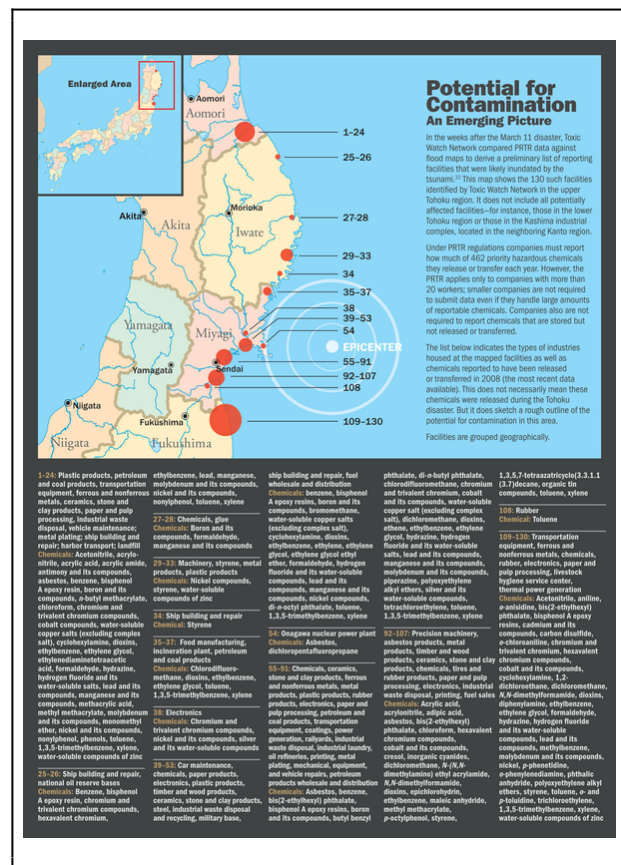
This is a revised and expanded version of Bird WA, Grossman E 2011. Chemical Aftermath: Contamination and Cleanup Following the Tohoku Earthquake and Tsunami. Environ Health Perspectives 119:a290-a301. doi:10.1289/ehp.119-a290 Online: 01 July 2011 [Environmental Health Perspectives].

Thirty days after the most powerful earthquake and tsunami in Japan's recorded history struck the northeastern coast of that country's main island, the city of Ishinomaki was a scene of devastation. The busy manufacturing and industrial port town in Miyagi Prefecture,¹ close to the epicenter of the quake, had suffered some of the worst damage of any community in the Tohoku region. Pulverized houses, skeletons of factories, and mountains of debris lined the dusty streets. Crumpled cars were tossed across graveyards, broken shipping containers strewn across fields. Ruptured oil tanks leaked glossy black liquid, bags of agrochemicals sat in iridescent puddles, and the doors to a shed labeled "Chemical Storehouse" flapped open, revealing an emptied room. Townspeople and officials walked through this huge field of wreckage, picking at the remains of their homes or simply gazing over the surreal landscape as if immobilized by the scale of damage.²

The magnitude 9.0 earthquake and tsunami of 11 March 2011 inundated 561 square kilometers of coastline, reaching up to 5 kilometers inland.³ The disaster wrought havoc from Aomori Prefecture in the north to Chiba Prefecture in the south (about 35 kilometers east of Tokyo); aftershocks affected areas far beyond the coast. The earthquake and tsunami combined may have killed over 20,000 people⁴ and damaged or destroyed more than 750,000 homes.^{5,6}

Damage to the region's industrial facilities also has been extensive. Oil refineries burst into

flames in the days after the disaster, sending black smoke billowing into the air. Sewer and gas lines burst, and old electrical equipment containing polychlorinated biphenyls (PCBs) was washed away.⁷ Petro- and agrochemical plants, iron foundries, steel works, and automotive, electronics, food processing, paper, plastics, and pharmaceutical plants were among those that suffered damage.



Potential for Contamination: An Emerging Picture

In the weeks after the March 11 disaster, Toxic Watch Network compared Pollution Release and Transfer Register (PRTR) data against flood maps to derive a preliminary list of reporting facilities that were likely inundated by the tsunami. This map shows the 130 such facilities identified by Toxic Watch Network in the upper Tohoku region. It does not include all potentially affected facilities—for instance, those in the lower Tohoku region or those in

the Kashima industrial complex, located in the neighboring Kanto region.

Download the printable copy (PDF file)

As cleanup continues in the disaster area, questions remain about the fate of chemical contaminants released by these damaged industrial facilities and other sources, and the environmental health hazards they might pose to the hundreds of thousands of people living and working in this area. Similar questions have arisen in the wake of hurricanes Katrina and Rita in 2005, the BP *Deepwater Horizon* disaster in the Gulf of Mexico in 2010, and the World Trade Center attacks on 11 September 2001. But in Japan, the vast human catastrophe and deepening Fukushima nuclear disaster have tended to eclipse these issues of chemical contamination.

The Industries Affected

The tsunami wiped out a strip of coast supporting a wide range of land uses and industries. The Iwate coast has many fishing communities along with cement and plywood manufacturers and a large iron foundry in the badly damaged city of Kamaishi.⁸ The Miyagi coastline had an estimated 1,000 factories, including a 145,000-barrel-per-day-capacity⁹ oil refinery in Sendai, marine products processing plants all along the coast, and various manufacturing industries near the ports.¹⁰ Rice farms in the Sendai area—which, according to one estimate, support approximately 8% of Japan's rice production¹¹—have also been affected. The Fukushima coast has fishery-related industries, along with auto parts factories and some chemical plants.¹²



A pile of debris burns in the open in Minamisanrikucho, Miyagi Prefecture, 14 April 2011.

© Winifred A. Bird

Further south, in the neighboring Kanto region, the Kashima industrial complex in Ibaraki Prefecture also suffered major earthquake and tsunami damage (although for the most part buildings remained intact).¹³ The Kashima coastal industrial zone is, according to Japanese accounts, home to the largest number of petrochemical industrial complexes in Japan.¹⁴ Other facilities here are a Mitsubishi Gas Chemical plant whose products include hydrogen peroxide and polycarbonates; an Adeka Company plant that produces chlorinated inorganic chemicals, flame retardants, caustic soda, and other chemicals along with oil-based food products; and a Mitsubishi Chemical plant that is Japan's largest ethylene production site. Facilities reporting damage include the Shin-Etsu Chemical Plant, a polyvinyl chloride (PVC) factory (Shin-Etsu's optical fiber plant in Fukushima was also damaged); Sumitomo Metal, where the earthquake toppled equipment and triggered gas tank fires; and an Asahi Glass plant that manufactures caustic soda, propylene oxide, fluorocarbon resin, and other chemicals, along with various types of flat glass used in building construction.

Dozens of high-tech and automotive production facilities also sustained damage from the quake and tsunami. Companies with plants located in Tohoku include Canon, Elpida, Fujitsu, Hitachi, Honda, Kyocera, Nissan, Panasonic, Texas Instruments (which described "substantial damage" to its semiconductor plant in Miho that affected gas, air, and chemical delivery systems), and Sony.¹⁵ Reports posted on company websites or noted in industry publications summarized damage very generally and primarily in terms of impact to business and production capacity. One exception is the bulletin from Freescale on its semiconductor plant in Sendai, which suffered serious damage. The company reported that when "personnel first reentered the fab [in late March] . . . they found broken ducts, pipes and windows and discovered that chemicals had leaked."¹⁶ Online industry publication *Medicine Hot News* reported damage at seven major pharmaceutical companies in the Tohoku region.¹⁷



A worker takes a break from cleaning up a decimated plywood factory on the wharf in Ishinomaki, Miyagi Prefecture

© Winifred A. Bird

As of early June, none of the affected major manufacturing companies had publicly reported in English the specific nature of any chemical releases related to the earthquake and tsunami. None contacted had information

to share beyond what was available by way of website bulletins and similar reports compiled by industry sector publications. Disaster reports from the Japanese Ministry of the Environment,¹⁸ Ministry of Economy, Trade, and Industry,¹⁹ and Fire and Disaster Management Agency²⁰ briefly described only a handful of spills including hydrochloric acid, chromium, and several unspecified hazardous materials, and damage to an ammonia tank; petrochemical spills were reported more extensively and in more detail. Here again, information beyond that in published reports was not available when requested by phone.

Another potential source of data are the reports local governments were required to submit to the central government concerning sites where “toxic and hazardous substance” spills may have occurred during the disaster. Although the individual reports are not publically available, they were compiled by the Ministry of Health, Labor, and Welfare’s Pharmaceutical and Food Safety Bureau (PFSB) and distributed to prefectural Pharmaceutical Affairs Bureaus on May 26. According to this document from the PFSB, which is available online, “measures to prevent the release of toxic and hazardous substances beyond company grounds in some cases functioned effectively, but in other cases, where facilities suffered extreme tsunami damage, instances of release beyond company grounds were observed.” The notice goes on to state that, “in many cases whole containers of toxic or hazardous substances or even entire storage facilities were washed away and not recovered.” A list detailing 75 instances of toxic or hazardous substance releases follows, along with a warning that cleanup workers and nearby residents need to be very careful as these substances are likely still present in the vicinity of damaged facilities. However, the quality of the reports on which the PFSB notice is based is undercut by the fact that they were left in the hands of extremely busy local officials: for instance, of 124 target sites in Ishinomaki, surveys were completed at just 27,

and at those sites no substance releases were reported.²¹

Data available through Japan’s Pollutant Release and Transfer Register (PRTR),²² comparable to the U.S. Environmental Protection Agency’s Toxics Release Inventory, give a more complete picture of what chemicals with potential environmental and health hazards may have been present at facilities in heavily impacted locations. In the weeks following the Tohoku disaster, Toxic Watch Network, a Tokyo-based nonprofit organization, combed the PRTR data to get a general idea of the chemicals that may have been onsite at affected facilities. The resulting list includes acrylamide, asbestos, benzene, bisphenol A, bromomethane (methyl bromide), cadmium, chromium compounds, chloroform, chlorodifluoromethane, ethylene glycol, dioxins, formaldehyde, lead, mercury, toluene, and xylene (see map).²³ Many of these compounds are respiratory hazards, neurotoxins, and/or carcinogens. Many are potentially acutely toxic. Some are also environmentally persistent, which raises potential issues of long-term contamination, particularly to local soil and water.

The numerous gas and oil fires that followed the earthquake would also have released hazardous pollutants, both chemical and particulate. In addition, debris that may have included plastics, wires, vinyl products, and insulation has been burned in large, open-air piles in the town of Minamisanrikucho, Miyagi Prefecture,²⁴ and possibly at other locations. Such fires have great potential to emit additional hazardous contaminants such as dioxins. These known human carcinogens result from incomplete burning of PVC, which is used extensively in wiring, construction materials, and numerous other consumer, industrial, and infrastructure applications. Dioxins can also be produced by burning seawater-soaked wood.²⁵

The tsunami caused extensive damage to agricultural land and facilities in Aomori, Iwate, Miyagi, Fukushima, Ibaraki, and Chiba prefectures,²⁶ where hogs and dairy and beef cattle are raised alongside crops that include rice and a variety of vegetables. Although the tsunami hit before the start of the main growing season, pesticides may have been stockpiled in agricultural locations impacted by flooding (according to the U.K.-based Agricultural Information Services consultancy, Japan is the world's second-largest crop pesticide market after the United States, with 60% of those pesticides applied to rice²⁷). Fertilizer and feed additives could also pose potential contamination hazards to soil and surface and groundwater, and to people encountering tsunami sludge and debris. Details are not available about specific fertilizers, pesticides, and other agricultural chemicals used at farm sites affected by the tsunami.

For a city like Ishinomaki, where paper, fertilizer, feed, and chemical factories are located directly adjacent to the shore, near homes and schools, and over six million metric tons of debris washed up²⁸, the giant wall of water destroyed conventional boundaries between "safe" and "hazardous." No one knows if oil and chemicals spilled in one place stayed put, washed out to sea, or ended up in another part of town.



A truck hauls debris and sludge deposited by the tsunami to a temporary dump site. Because much of the sludge has already been moved from its original location, identifying that which came from potentially-contaminated sites is a challenge.

© Winifred A. Bird

The tsunami may also have carried tsunami sludge from the bottom of bays up onto the land. "Ships come in and out of harbors, and they leak oil. There's trash and other materials [on harbor floors]," said environmental engineer Toshiaki Yoshioka, who is a member of the Japan Society of Material Cycles and Waste Management (JSMCWM) Disaster Waste Management and Reconstruction Task Team, an academic association that has been surveying disaster waste throughout Tohoku and helping local governments develop plans to manage it. Yoshioka said the tsunami sludge could also include heavy metals, PCBs, and other pollutants washed down rivers by mines and factories before strict anti-dumping laws were passed in the late 1960s and 1970s.²⁹

The problem of toxics on the harbor floors highlights the hazards that modern industrial society adds to the age-old destructive force of natural disasters. “In the past, what came up with the tsunami from the ocean was not hazardous,” Yoshioka said. “Now we are using all sorts of materials, and everything has been mixed together [by the tsunami]. If you just burn or bury [tsunami and earthquake waste] the risk to the environment is very high. We need to process the waste properly, or it will come back to haunt us.”

Assessing the Damage

Government³⁰ and independent³¹ estimates put disaster waste in the tsunami inundation area at about 25 million metric tons, and its makeup varies hugely across the disaster area. Masato Yamada, chief of the Research Center for Material Cycles and Waste Management at Japan’s National Institute for Environmental Studies (NIES), the research arm of the Ministry of the Environment, pointed out that treating all the waste as hazardous would not only be extremely expensive and time-consuming, but also would rule out the possibility of recycling some materials during the reconstruction. Yet it’s not yet clear which areas need to be treated with particular care.

“I think the tsunami sludge is probably not that dangerous except for in a few ‘hot spots’—the problem is finding them,” Yamada said. “We need to know what was in the area before the tsunami and earthquake hit. Were there industrial chemicals or agrochemicals in a certain place? That could become a hot spot.”

To an extent, that information does exist. Japan’s PRTR regulations require companies to report to local governments the quantity of 462 designated hazardous chemicals that they release into the environment or transfer to a different location each year.³² This information is compiled by the central government and publicly available.³³

But the PRTR law applies only to companies with more than 20 workers that handle certain chemicals over a specified amount. Smaller companies aren’t required to submit data even if they handle large amounts of toxic chemicals - and Keio University historical sociologist Eiji Oguma points out that industry in the Tohoku region is characterized by small scale manufacturers.³⁴ Companies are also not required to report on chemicals that are stored but not released, an information gap Kyoto University disaster planning expert Nagahisa Hirayama calls “a very big problem.” Although some of that missing information is supplied to local and central government offices under Japan’s Fire Services Act,³⁵ which aims to prevent fires and limit damage from disasters including earthquakes, it is not made public in the same way that PRTR data are, according to Yoshiaki Matsuki of the Japanese Fire and Disaster Management Agency.

PRTR data—and often local disaster response plans in the United States—also miss entire categories of potential contaminants: fuels such as propane and gasoline used at factories and in vehicles; materials that are bound up in equipment and structures, including asbestos, wiring components, nonasbestos insulation, carpeting, and other flooring materials that can pose health hazards when burned; pesticides and other agrochemicals kept on farms; and chemicals kept in small quantities at homes, shops, and other nonindustrial locations. According to Toxic Watch Network director Shigeharu Nakaji, information about PRTR-listed chemicals released during the disaster will be reported to the government by June 2011 and made public early in 2012. That reporting, however, will not have informed any needed protective measures during the first weeks of cleanup.

Even existing data appeared to have barely been touched by overwhelmed scientists and government officials in the first two months following the disaster. In May local officials in

Ishinomaki and Kamaishi said they had not begun detailed investigations of damage to industrial areas or resulting chemical contamination because they were still focused on urgent relief and recovery work.³⁶ By the middle of that month the Ministry of the Environment had commissioned the JSMCWM Disaster Management and Reconstruction Task Team to come up with a strategy for identifying potential toxic hot spots and safely disposing of tsunami sludge. The group published a detailed proposal on July 5³⁷; on the 13th, four months and two days after the tsunami hit, the Ministry published its own much-simplified version of those guidelines.³⁸

The Ministry guidelines call for a division of sludge into three categories based on its proximity to facilities that handled toxic materials. These facilities are to be identified using PRTR data “etc.” Sludge at locations near heavily damaged facilities that handled toxic materials is to be chemically analyzed before disposal, while that near less-damaged facilities is to be screened on-site and analyzed when necessary. When a facility known to have handled toxic substances is not in the immediate vicinity of the clean-up work, the guidelines recommend using sight and smell to identify potentially hazardous sludge. However, the document notes that, “in situations where it is difficult to follow these guidelines, such as where sludge removal is already underway, flexibility is requested in appropriately disposing of sludge.” It is unclear from the document how the Ministry will ensure clean-up companies are aware of the guidelines, how these companies will be informed of the exact location of facilities that once handled toxic substances, or how the many information gaps left by the PRTR data should be filled in.

Testing for common contaminants is possible even without information about the original location of hazardous materials, however, and such monitoring is a growing focus in the Japanese disaster response. But environmental

contaminant monitoring and testing will find only what the tests and instruments have been calibrated to seek. The siting of environmental testing in relation to potential contamination sources can also influence results and thus lead to very different decisions about resident and community health and safety, according to Scott Frickel, a Washington State University associate professor of sociology who studied contamination after Hurricane Katrina.³⁹ This is an issue that has come up in the aftermath of both natural disasters like Hurricane Katrina and industrial accidents like the *Deepwater Horizon* disaster.

In Japan the ongoing recovery and related testing—which is proceeding at varying paces in different regions—falls roughly into three phases. Early on, when many disaster victims and emergency response workers are spending time surrounded by dusty debris, the tsunami sludge, air, and smoke from open-air waste burning are logical places to begin testing. (However, NIES’s Yamada pointed out that because disease-causing pathogens in the tsunami sludge are a big concern at this stage, thorough testing must be balanced with speedy cleanup.) As recovery proceeds and debris is moved from temporary to permanent storage locations, testing is needed to ensure contaminated materials are not recycled or improperly disposed of. Later, as residents begin rebuilding the worst-hit areas, redigging buried wells, fishing along the coast, and planting crops, testing for soil, surface water, and groundwater contamination will become increasingly important.

Routine monitoring of water, soil, and air quality is mainly the responsibility of prefectural governments in Japan. However, although officials in Fukushima, Miyagi, and Iwate prefectures said they were continuing routine tests wherever possible, as of the end of April they had not begun any testing specifically related to the disaster.⁴⁰ “It’s a matter of priority,” said environmental policy

expert Yoshinobu Kitamura, who is serving on a prefectural disaster waste committee in Iwate. “The first priority [for prefectural officials] is to clean stuff up and keep transport routes open. Sure, the government expects contamination, but attention to chemicals is a low priority right now.” Harried prefectural and municipal officials echoed that explanation.



Bags of fertilizer lie strewn about the grounds of a factory in Ishinomaki, Miyagi Prefecture, 10 April 2011.

© *Winifred A. Bird*

That situation had begun to change by June, with the central government stepping in to take charge of testing. A supplemental disaster budget approved May 2 for the Ministry of the Environment included ¥400 million (about US\$5 million) for environmental monitoring aimed at assessing contamination from asbestos and hazardous materials leaked from factories and other sources.⁴¹ Led by the central government in consultation with local and prefectural officials, the first round of tests on soil, air, groundwater, public water areas (a legal category that includes rivers, lakes, ports, water lines, and other public water resources), and seawater and the seafloor began in June,⁴² and results had begun to be released in July.⁴³ Although most tests did not turn up levels of

contaminants exceeding national health and safety standards, in a few instances levels of boron, arsenic, and fluorine in rivers did exceed these standards. In tests of seawater and ocean sediment, levels of brominated flame retardants⁴⁴ and hydrocarbons falling within the range of pre-disaster test results but relatively high within the context of the current round of tests were identified at several locations.

The Ministry had already carried out preliminary asbestos monitoring at 15 locations in three prefectures by mid-April; results fell within legally allowed limits.^{45,46} In June, Ministry officials said asbestos testing had begun at approximately 130 locations including temporary houses and shelters, building demolition sites, and areas still covered in debris in Aomori, Iwate, Miyagi, Fukushima, and Chiba. But Naoki Ikeda, an Osaka lawyer with experience prosecuting soil contamination and worker health cases, warned that continued public pressure will be needed to ensure proper testing continues throughout the cleanup. Although strict environmental impact assessments are required for major public projects like dams, ports, and the construction of large garbage dumps, the same does not hold for disaster cleanup itself.



Tsunami sludge blocks the doors of a shop in Ishinomaki, Miyagi Prefecture, 10 April 2011.

© Winifred A. Bird

One exception to the general lack of environmental monitoring early on was in Sendai, Miyagi's largest city, which has legal responsibilities similar to a prefecture. In April the municipal government tested tsunami sludge samples from 32 locations, including schools, residential areas, and parks, for heavy metals, cyanide, arsenic, and PCBs.⁴⁷ The tests turned up low levels of lead, PCBs, and arsenic at several locations—although Tetsuo Ishii, director of the city's Environmental Management Section, said levels were similar to those detected in Sendai before the tsunami. The JSMCWM task team also tested tsunami sludge from 13 locations in Sendai early on for persistent organic pollutants (POPs), total petroleum hydrocarbons, *n*-hexane extractable substances, pH, and water content. All results

fell below acceptable legal limits, but several samples showed high oil and POP content compared with the other samples. The researchers concluded that areas where these samples were taken may have been contaminated by damaged petrochemical factories and recommended waste from the sites be handled separately.⁴⁸

JSMCWM followed up these early tests with a wider slate of tests on samples collected at 62 locations in the tsunami inundation zone in Iwate and Miyagi prefectures, releasing the results in early July. Although most test results fell below legally acceptable standards, they exceeded the standards for lead, arsenic, boron, or fluorine content in 25 cases. In several other cases, levels of dioxins, PCBs, and DDTs significantly higher than levels typically detected in pre-disaster environmental monitoring were detected. The report noted that not all of these results could automatically be attributed to pollution caused by the tsunami; for instance, lead and arsenic could have natural rather than industrial sources.^{49,50}

Toxic Watch Network will also begin carrying out a three-year soil- and air-quality monitoring project in the disaster area this fall, funded by a 14-million-yen grant from the Mitsui & Co., Ltd Environmental Fund (part of the grant will go towards radiation monitoring).⁵¹

Protecting Residents, First Responders, and Other Cleanup Workers

Life in the disaster area, of course, has not stood still. Families are digging through the collapsed remains of their homes. Disaster victims—many of them aged and weak—are living in shelters in the midst of debris. Swarms of professional and volunteer cleanup workers and members of Japan's military, the Self Defense Force, are scooping up tsunami sludge, clearing streets, and hauling debris to temporary disposal sites seven days a week.

According to an Asahi Shimbun report, just over a third of the 21,830,000 metric tons of disaster debris in Iwate, Miyagi, and Fukushima had been moved to temporary disposal sites by early July; the rest remained piled in towns and fields all along the coast.⁵²

Despite the lack of information about the contaminants in the dust and tsunami sludge, one month after the disaster many volunteers and contracted cleanup workers in Ishinomaki and the coastal city of Minamisanrikucho were clearing debris wearing only cotton gloves, flimsy paper masks, or no protective equipment at all. Access to damaged buildings was only partially restricted, even though aftershocks continued. It was possible to drive and walk freely through damaged industrial areas. Only a few factories were cordoned off or marked with “danger” signs.⁵³

By law the professional cleanup workers and employees of damaged factories who are doing most of the cleanup work in industrial areas have a right to better protection. Japanese labor law holds employers responsible for providing proper personal protective equipment and educating workers about the risks should they fail to use it,⁵⁴ and both industry organizations and government agencies have taken steps to make sure the private cleanup companies contracted to do much of the cleanup work follow through.

Ayako Toyo, a media officer with the Operations Division of the National Federation of Industrial Waste Management Associations, said the 47 prefecture-level associations that make up the federation have provided safety information to companies working in the disaster area. Sugio Furuya, secretary general of the Japan Occupational Health and Safety Resource Center, said his organization—a successor to a similar organization founded by two of Japan’s disbanded national labor union federations, Sohyo and Churitsu Roren—was carrying out an information campaign as well.

The Ministry of Health, Labor, and Welfare also posted worker safety information in shelters and at local labor bureaus,⁵⁵ and had distributed 90,000 masks in the disaster area by April 11⁵⁶; unknown thousands more were distributed in later weeks. Officials from the Ministry of Labor’s Labor Standards Bureau carried out inspections of cleanup worksites in selected cities in three prefectures on April 27 and 28 to check that workers were being properly protected.^{57,58}

No information has been made public about the findings of these inspections, but Hisayuki Sato, head of the Health and Safety Department at the Iwate Labour Bureau, notes that use of protective equipment has been uneven across work sites. Yuji Sakata, an official in the Ministry of Labor’s Health and Safety Planning Section, said the ministry planned to continue these inspections periodically. For its part, the Environment Ministry issued guidelines soon after the disaster hit for handling asbestos and old electrical conductors and transformers, which could contain PCBs.⁵⁹

Health and safety guidelines for American response workers participating in cleanup and recovery efforts via the U.S. governmental or other organizations in Japan are outlined by the National Institute of Environmental Health Sciences (NIEHS) Worker Education Training Program in an online training tool titled “Controlling Hazards During the 2011 Earthquake and Tsunami Response.”⁶⁰ Designed to walk first responders through the range of potential biological, chemical, radiation, and other hazards they may encounter, these guidelines direct workers to follow their employers’ safety and health rules, including requirements for personal protective equipment, which are mandated by the U.S. Occupational Safety and Health Administration. Comparable training manuals were developed by the NIEHS for the *Deepwater Horizon* disaster and other response efforts.

But in disasters of great geographic scope requiring large numbers of response workers, it is challenging to ensure that all workers receive adequate health and safety training and personal protective equipment, as evidenced by experiences following the *Exxon Valdez* oil spill and the *Deepwater Horizon* disaster. Judging by the number of cleanup workers observed in Ishinomaki and Minamisanrikucho without personal protective gear shortly after the earthquake, this was clearly a problem in Japan.

The thousands of volunteers on the front lines of the cleanup are in an even more vulnerable position than first responders. Ikeda, the Osaka environmental lawyer, said Japan's strict worker health and safety laws do not protect volunteers because they are not employed by anyone. In interviews conducted in mid-April, volunteers cleaning tsunami sludge from streets and shops in Ishinomaki with Peace Boat, one of the largest nonprofit organizations working in the area, said they received scant safety training and were instructed to bring their own personal protective equipment but were not regularly reminded to use it. Simon Rogers, Peace Boat's safety officer hired specifically for this operation, said in late April that the situation had improved greatly. By then, volunteer team leaders were receiving six hours of safety training, a safety manual had been created, and most volunteers were wearing goggles, leather gloves, and masks during their work shifts, he said. But those improvements are due to the organization's independent efforts; no coordinated nationwide effort exists to ensure all disaster volunteers - many of whom come to the disaster area individually or in small groups, with little or no experience handling toxics - receive uniform safety training and proper equipment.⁶¹

Information regarding the health of residents, workers, and volunteers in the disaster area is so far scarce, aside from that related to radiation exposure. An official in the Ministry of

Health, Labor, and Welfare speaking on condition of anonymity said in early June that local government offices in the disaster area did have health data, especially for people living in shelters, but that "the problem for us is how to collect that information. Everyone in the disaster area is too busy to organize and send it in [to the central government]."

The Health Sciences Division of the ministry also intended to start free health screenings targeting thousands of people in temporary housing, shelters, and damaged neighborhoods in parts of Iwate, Miyagi, and Fukushima, according to the official. However, the program has so far been plagued by difficulty. "It's a conservative area, and many people don't trust the central government right now. Because of decentralization, local governments are usually in charge of these kinds of health checks, so if we step in there is resistance. We're planning to do the screening where we can get cooperation from local communities," the official said. Because of the nuclear disaster, health checks are being carried out by Fukushima Prefecture for all citizens, including internal radiation exposure checks for people living near the damaged Fukushima Daiichi plant.⁶²

Furuya said information regarding the health of cleanup workers was extremely limited as of early June. "We are monitoring the asbestos and dust situation on the ground, but health surveys of workers have not yet begun, either by us or by the Ministry of Health, Labour, and Welfare," he said. "While no formal reports have come out yet, we're hearing from doctors on the ground that respiratory complaints have increased among both workers and residents in the disaster area, probably because of the dust." Nine cases of tetanus were also reported in the disaster area between March 20 and April 20, all caused by injuries sustained during the earthquake or tsunami.^{63,64}

A Global Concern

The earthquake and tsunami that hit Japan March 11 rendered meaningless many of the standard procedures used to assess, handle, and protect workers and residents from chemical hazards. Labels and signs went missing. Supervisors weren't always available to consult. City halls and factory offices were washed away, and the need to care for thousands of homeless survivors swamped the public officials who might otherwise have focused on longer-term environmental health threats.

But is it inevitable that the health and safety challenges now facing Japan would follow a disaster that—to borrow a phrase echoed endlessly in the months after the earthquake and tsunami—“exceeded all predictions”? Or are there measures Japan and other countries can take to ensure that even in an event of this scale, residents and workers in impacted areas are protected from chemical threats?

Since the earthquake struck, Japanese government and industry have come under heavy criticism for their failure to prepare for a nuclear disaster like the one at the Fukushima Daiichi power plant.^{65,66,67,68} Kyoto University disaster planning expert Hirayama said some of the same criticisms apply more broadly. “Japan had no concrete plan for dealing with chemically contaminated disaster waste before the tsunami hit,” he said. Ideally such plans would include detailed procedures for quickly assessing whether debris is hazardous or not, and guidelines for handling the most toxic debris.

Sendai's Yoshioka added that bureaucratic sectionalism posed another man-made obstacle during the cleanup: information as well as responsibility for environmental monitoring and cleanup is divided among various ministries and branches of local governments, which increases the likelihood that, in the end, none will fulfill their shared responsibility.

The problem is not Japan's alone. In the United States detailed chemical emergency management plans are established by the Emergency Planning and Community Right-to-Know Act (EPCRA) and the Federal Emergency Management Agency (FEMA),⁶⁹ and environmental monitoring conducted by the Environmental Protection Agency (EPA), state environmental agencies, and other federal and local government entities is often part of a federal or state government disaster response. But the question of how to address health risks posed by chemical contaminants released in the course of a disaster can easily become controversial. Disputes over where, when, and how to conduct chemical hazard assessments have arisen repeatedly in the United States—for example, during the *Exxon Valdez* cleanup in 1989, the World Trade Center cleanup after 9/11, in the aftermath of hurricanes Katrina and Rita, and during the *Deepwater Horizon* disaster and response.

Protecting emergency response workers from potential chemical and other health hazards has also been a subject of intense discussion in these events. As National Council for Occupational Safety and Health executive director Tom O'Connor points out, “Whether occupational safety and health agencies should enforce standard safety rules during an emergency or whether they should operate in a ‘non-enforcement mode’ has been a hotly debated topic in the U.S.” One example involves the shortened hazardous waste operations (HAZWOPER) training that was instituted for certain emergency workers during the *Exxon Valdez* oil spill response⁷⁰ to facilitate rapid mobilization of a large oil spill cleanup work force. During the *Deepwater Horizon* response, intense discussion revolved around whether the shorter courses provide adequate worker training and protection.

Although certain reporting about the use and storage of hazardous chemicals is legally required by EPCRA and by local government

emergency planning programs, the reporting requirements themselves resulted from a political process and do not include all hazardous materials. Similarly, decisions about what information is made public and what tests are conducted are often subject to political negotiations. Therefore, what is considered politically or, indeed, logistically feasible can take precedence over what may be ideal in terms of health protections.

Assessments of potential chemical health hazards resulting from disasters also are affected by how much is known about predisaster environmental conditions and local levels of pollution. How such conditions are taken into consideration inevitably influences what is considered “normal” or “safe” for residents and workers in the affected area.⁷¹

But again, health and safety are not the sole considerations in these assessments; confidential business and security considerations, practicality, cost, and the desire to return to business as usual all come into play. All these complications prompt the question of whether more emphasis should be placed on the kind of upstream chemical pollution prevention and hazard elimination that can be achieved through green chemistry.⁷² A transition to more environmentally benign materials and manufacturing processes could help protect community, environmental, and emergency worker health and safety, especially when natural and other disasters exceed our worst predictions. Some such changes in this direction have already been made, prompted by security concerns. For example, in the U.S., water treatment plants in Michigan and Ohio have changed processes to eliminate the use of chlorine gas that poses extreme hazards in an uncontrolled release. As of March 2010, according to a survey by the Center for American Progress⁷³, more than 550 U.S. water treatment plants had changed processes to eliminate the use of chlorine or sulfur dioxide

gas. Other facilities that synthesize chemical products or use them in power production processes have eliminated the use of anhydrous ammonia and sulfur dioxide, replacing it with solid forms of these chemicals, thereby eliminating the possibility of toxic gas releases.⁷⁴

In the course of reporting this article, we contacted federal agencies, including the Centers for Disease Control and Prevention, EPA, FEMA, and NIEHS in the United States, and a number of corresponding agencies in Japan, to ask how emergency management plans for chemical hazards have worked in the course of actual disasters and how assessment of such potential hazards have been evaluated in the immediate aftermath of disasters. These agencies directed us to the copious—but general—information available online that describes existing chemical emergency management plans and regulations. But many open questions remain about the implementation and adequacy of these policies, particularly in the event of a disaster with such wide-ranging potential health hazards as the Tohoku earthquake and tsunami.

The situation in Japan is evolving, and it’s clear that in an event like the March 11 disaster, primary concerns will always be the immediate safety and recovery for everyone affected. But even during initial rescue efforts, responders need to be protected against chemical hazards, and when cleanup and rebuilding efforts begin, the potential health hazards posed by chemical contaminants become increasingly important. Judging from the extreme difficulty of obtaining concrete, detailed information about potential chemical hazards following the Japan disaster, this appears to be an aspect of emergency preparedness that, despite well-established formal disaster-response plans, remains inadequately addressed.

Winifred A. Bird is a freelance journalist living in Nagano, Japan. Her work has appeared in the *Japan Times*, *Science*, *Yale Environment 360*, *Dwell*, and other publications. **Elizabeth Grossman**, a Portland, OR-based environmental and science writer, has written for *TheAtlantic.com*, *Yale Environment 360*, *Scientific American*, *The Washington Post*, and other publications. Her books include [Chasing Molecules](#) and [High Tech Trash](#).

Recommended citation: Winifred A. Bird and Elizabeth Grossman, Chemical Contamination, Cleanup and Longterm Consequences of Japan's Earthquake and Tsunami, The Asia-Pacific Journal, Volume 9, Issue 33, No 1, August 15, 2011.

Related articles

- Kodama Tatsuhiko, [Radiation Effects on Health: Protect the Children of Fukushima](#)
- David McNeill and Jake Adelstein, [What happened at Fukushima?](#)
- Koide Hiroaki, [The Truth About Nuclear Power: Japanese Nuclear Engineer Calls for Abolition](#)
- Chris Busby, Norimatsu Satoko and Narusawa Muneo, [Fukushima is Worse than Chernobyl – on Global Contamination](#)
- Yuki Tanaka and Peter Kuznick, [Japan, the Atomic Bomb, and the "Peaceful Uses of Nuclear Power"](#)
- Paul Jobin, [Dying for TEPCO? Fukushima's](#)

Nuclear Contract Workers

- Say-Peace Project and Norimatsu Satoko, [Protecting Children Against Radiation: Japanese Citizens Take Radiation Protection into Their Own Hands](#)

See other articles on Fukushima in the [What's Hot](#) section on *Asia-Pacific Journal: Japan Focus*

References and Notes

1. Japan has 47 prefectures, each of which—like a U.S. state—has its own governor, laws, and legislative departments. The prefectures are divided into 8 regions. The Tohoku region, covering the northern tip of Japan's main island of Honshu, bore the brunt of the March 11 disaster. Ibaraki and Chiba prefectures, in the neighboring Kanto region to the south, also were affected.
2. Bird WA. Firsthand observation, Ishinomaki, Miyagi Prefecture (10–13 Apr 2011) [this and subsequent firsthand observations and interviews are unpublished].
3. Geospatial Information Authority of Japan. Map of Tsunami Inundation Zone. General Condition [in Japanese]. Tsukuba, Japan: Geospatial Information Authority of Japan (updated 18 Apr 2011). Available: <http://tinyurl.com/4tefbzy> [accessed 9 Jun 2011].
4. As of 28 July 2011 there were 15,642 confirmed deaths and 5,001 missing persons, according to the National Police Agency of Japan. (http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf)
5. As of 28 July 2011 there were 110,746

- totally collapsed, 133,668 half-collapsed, and over 480,000 partially damaged properties, according to the National Police Agency of Japan.
6. National Police Agency of Japan. Damage Situation and Police Countermeasures. 28 July 2011. Tokyo, Japan: National Police Agency of Japan (2011). http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf.
 7. Extremely Poisonous PCBs Leaked as a Result of the Tsunami [in Japanese]. Asahi Geino (9 June 2011). Available: <http://tinyurl.com/5vt52z4> [accessed 9 Jun 2011].
 8. Bird WA. Interview with Yukie Fujiwara, Iwate Prefecture Industry Department (28 Apr 2011).
 9. ENEOS Guide Book—Sendai Oil Refinery Guidebook [in Japanese]. Sendai, Japan: JX Nippon Oil & Energy (2010). Available: <http://tinyurl.com/3jymdhr> [accessed 9 Jun 2011].
 10. Bird WA. Interview with Hitoshi Sakai, Miyagi Prefecture Industry Department (28 Apr 2011).
 11. Alabaster J. Japanese Affected by Tsunami Hope for Swift Soil Recovery. Associated Press via Ag Week (5 April 2011). Available: <http://tinyurl.com/5vjkkof> [accessed 9 Jun 2011].
 12. Bird WA. Interview with Hitoshi Watanabe, Fukushima Prefecture Industry and Commerce Department (2 May 2011).
 13. Operations Stop at One Factory after Another in the Kashima Industrial District: Huge Impact on Downstream Automotive, Electronics, and Other Industries (Disaster Map Series) [in Japanese]. Toyokeizai Online, Business section (23 Mar 2011). Available: <http://tinyurl.com/6f9th6k> [accessed 9 Jun 2011].
 14. Samata K. Industrial Zone Still Rebuilding. Daily Yomiuri Online, Business section (30 April 2011). Available: <http://tinyurl.com/6b8hcqm> [accessed 9 Jun 2011].
 15. Japan Quake: Tracking the Status of Fabs in Wake of Disaster. EE Times, News & Analysis section (14 Mar 2011). Available: <http://tinyurl.com/696crted> [accessed 9 Jun 2011].
 16. Yoshida J. Freescale Sendai Fab Is Latest Quake Victim. EE Times, News & Analysis section (6 April 2011). Available: <http://tinyurl.com/5smd95k> [accessed 9 Jun 2011].
 17. Pharmaceutical Companies Also Impacted in Tohoku Disaster [in Japanese]. Medicine Hot News (17 Mar 2011). Available: <http://tinyurl.com/66zzwvn> [accessed 9 Jun 2011].
 18. Ministry of the Environment. Regarding the Tohoku Disaster. Tokyo, Japan: Ministry of the Environment, Government of Japan (2011). Available: <http://tinyurl.com/42p8oo7> [accessed 9 Jun 2011].
 19. Ministry of Economy, Trade, and Industry. Overview of Damage Situation and METI Measures. Tokyo, Japan: Ministry of Economy, Trade, and Industry, Government of Japan. Available: <http://tinyurl.com/3c92426> [accessed 9 Jun 2011].
 20. Fire and Disaster Management Agency. Regarding the Tohoku Disaster, 118th report [in Japanese]. Tokyo, Japan: Fire and Disaster Management Agency, Government of Japan (9 May 2011).
 21. 26 May 2011 Administrative Notice from the Ministry of Health, Labor, and Welfare Pharmaceutical and Food Safety Bureau, “「東北地方太平洋沖地震に伴う津波による毒物又は劇物の流出事故等に係る対応について」における集計結果について”
 22. Japan Society of Material Cycles and Waste Management, 5 July 2011, “津波堆積物処理指針”

23. [Preventing Toxic Terrorism: how Some Chemical Facilities are Removing Danger to American Communities](#), 24 April 2006 [accessed 10 August 2011]
24. Ministry of the Environment. Order for Enforcement of the Act on Confirmation, Etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof. Cabinet Order No. 138 of March 29, 2000 (revised 27 Oct 2004 by Cabinet Order No. 328). Tokyo, Japan:Ministry of the Environment, Government of Japan. Available: <http://tinyurl.com/3gkd3jk> [accessed 9 Jun 2011].
25. Toxic Watch Network. Companies in the Tohoku Tsunami Disaster Area Covered by the PRTR Law, and the Names of Released and Transferred Substances Reported by Those Companies: Towards Minimizing Harm from Hazardous Chemicals during the Reconstruction [in Japanese] [website]. Available: <http://tinyurl.com/68pkm8d> [accessed 9 Jun 2011].
26. Bird WA. Firsthand observation, Minamisanrikucho, Miyagi Prefecture (14 Apr 2011). Also documented with photos in the 16 Apr 2011 "Onsite Memo" from Minamisanrikucho and Kessennuma, by the Japan Society for Material Cycles and Waste Management Disaster Management and Reconstruction Task Team [in Japanese]. Available: <http://tinyurl.com/3hvw9aw> [accessed 9 Jun 2011].
27. Yasuhara A, et al. Formation of PCDDs, PCDFs, and coplanar PCBs from incineration of various woods in the presence of chlorides. *Environ Sci Technol* 37(8):1563-1567. 2003. doi:10.1021/es020948o [Find this article online](#)
28. Johnson R. Japan's 2011 Earthquake and Tsunami: Food and Agricultural Implications. Washington, DC: Congressional Research Service (13 Apr 2011). Available: <http://tinyurl.com/3zde5d4> [accessed 9 Jun 2011].
29. AIS. Agricultural Crop Pesticide Use-Studies & Reports [website]. London, UK:Agricultural Information Services. Available: <http://tinyurl.com/44phyro> [accessed 9 Jun 2011].
30. Asahi Shinbun July 8 2011. 「がれき撤去やっと35日 被災3県、焼却施設も未整備」 The article states that of 37 towns surveyed by the paper, Ishinomaki had the most disaster debris, with 6,160,000 metric tons - more than the total for all of Iwate Prefecture, and the equivalent of 106 average years' worth of city debris. <http://v.go-iwate.org/?p=4412>.
31. Institute for International Cooperation. Environmental Pollution Control Measures. In: Japan's Experience in Public Health and Medical Systems. Tokyo, Japan: Institute for International Cooperation, Japan International Cooperation Agency (Mar 2005). Available: <http://tinyurl.com/3cchm4x> [accessed 9 Jun 2011].
32. Unable to Keep Up with Disaster Waste: A System for Cooperating on a National Scale Is Indispensable. *Eco Japan* (9 May 2011). Available: <http://tinyurl.com/433n5h7> [accessed 9 Jun 2011].
33. Hirayama N. Estimated Amount of Tsunami Disaster Waste from the Tohoku Earthquake [in Japanese]. Presented at the Emergency Briefing Session on Tohoku Disaster Waste, hosted by the Japan Society of Material Cycling and Waste Management, 30 Apr 2011, Tokyo, Japan. Using existing computerized simulations of the tsunami inundation area and data on the number of households in the area, Hirayama predicted 26.73 million metric tons of waste.

34. NITE. Chemical Management Field, Information on PRTR, Law/Cabinet Order [website]. Tokyo, Japan: National Institute of Technology and Evaluation (2008). Available: <http://tinyurl.com/3lq22jt> [accessed 9 Jun 2011].
35. Ministry of the Environment. PRTR Information Plaza Japan [website]. Tokyo, Japan: Ministry of the Environment, Government of Japan. Available: <http://tinyurl.com/6g9unvj> [accessed 9 Jun 2011].
36. Oguma, E. "The Hidden Face of Disaster: 3.11, the Historical Structure and Future of Japan's Northeast." *The Asia-Pacific Journal*, Vol 9, Issue 31 No 6, Aug 1, 2011.
37. Fire Service Act of 1948 (Japan). Act No. 186 of 1948. Amendment: Act No. 41 of 2008. Available: <http://tinyurl.com/4ybtb6w> [accessed 9 Jun 2011].
38. Bird WA. Interviews with Tomofumi Miura, Ishinomaki Environment Division (29 Apr 2011), and Shigeyoshi Iwama, Kamaishi Environment Department (28 Apr 2011).
39. Ministry of the Environment, 13 July 2011, "東日本大震災津波堆積物処理指針"
40. Frickel S, Vincent MB. Hurricane Katrina, contamination, and the unintended organization of ignorance. *Technol Soc* 29(2):181-188. 2007. doi:10.1016/j.techsoc.2007.01.007 [Find this article online](#)
41. Bird WA. Interviews with Hitoshi Suzuki, Fukushima Prefecture Institute of Environmental Research (2 May 2011), Katsumi Shoji and Hiroyuki Akasaka, Miyagi Prefecture Environment Department (28 Apr 2011), and Noriko Abe, Iwate Environmental Preservation Department (28 Apr 2011).
42. Ministry of the Environment. Overview of the 2011 Supplementary Budget [in Japanese]. Tokyo, Japan: Ministry of the Environment, Government of Japan. Available: <http://tinyurl.com/6l4nlk7> [accessed 9 Jun 2011].
43. Ministry of the Environment. Regarding Environmental Monitoring in the Great Eastern Japan Earthquake and Tsunami Disaster Area [in Japanese] [press release]. Tokyo, Japan: Ministry of the Environment, Government of Japan (2 May 2011). Available: <http://tinyurl.com/5tcjtvj> [accessed 9 Jun 2011]. Supplementary Information available: <http://tinyurl.com/6ekrtcZ> [accessed 9 Jun 2011]. Additional details of the testing are described in the Supplementary Information as follows:
Air quality testing: Tests planned in Iwate, Miyagi, Fukushima, and Ibaraki prefectures at several dozen locations where large numbers of disaster victims are living, in particular industrial areas where the threat of chemical contamination is high, areas with a lot of tsunami sediment, and areas where there are concerns about dioxins and other harmful substances. Tests will target nitrogen dioxide, sulfur dioxide, suspended particulate matter, carbon monoxide, benzene, toluene, dioxins, and other high-priority pollutants.
Public water areas: Tests are planned for about 300 locations along the tsunami-damaged coastline from Aomori to Ibaraki prefectures, with an emphasis on industrial areas where there is a high threat that hazardous materials leaked. Tests will target arsenic, lead, PCBs, dioxins, biochemical oxygen demand, and chemical oxygen demand.
Groundwater: Tests are planned for about 250 locations in Aomori, Iwate, Miyagi, Fukushima, and Ibaraki prefectures, and will take place at wells in areas where facilities handling hazardous substances sustained damage, as well as other areas where chemical contamination is suspected. Tests will target organochlorine

compounds, arsenic, lead, and dioxins. **Soil:** Tests will take place at several dozen locations (especially industrial areas) where hazardous material leaks or dioxin contamination are thought to have occurred in Iwate, Miyagi, and Fukushima prefectures. Tests will target dioxins and 25 regulated hazardous soil contaminants including PCBs and chromium compounds. **Seawater and seafloor:** Tests will take place at three locations each on seven traverse lines in the ocean off the Iwate, Miyagi, and Fukushima coasts. Tests will target oil content and hazardous substances including PCBs, 1,2-dichloroethene, and dioxins. **Tsunami sediment:** Tests will take place in about 50 locations.

44. PDFs in Japanese outlining the results of each category of tests are available on the Environment Ministry's disaster response webpage, under the subheading 「東日本大震災の被災地における環境モニタリング調査について」
45. Information on the possible environmental health threats associated with brominated flame retardants can be found in Linda S. Birnbaum and Daniel F. Staskal's article 2004 article in *Environmental Health Perspectives*, "Brominated Flame Retardants: Cause for concern?"
46. Hosaka TA. Japan Disaster's Other Hidden Danger: Asbestos. Associated Press via msnbc.com, Asia-Pacific section (27 Apr 2011). Available: <http://tinyurl.com/5t3ycgs> [accessed 9 Jun 2011].
47. Ministry of the Environment. Results of the Preliminary Survey of Asbestos Concentration in the Air [in Japanese]. Tokyo, Japan: Ministry of the Environment, Government of Japan (27 Apr 2011). Available: <http://tinyurl.com/3k69wkc> [accessed 9 Jun 2011]. According to the report, the concentration of asbestos fibers in the air at 15 disaster-impacted locations in Ibaraki, Miyagi, and Fukushima ranged from 0.08 fibers per liter to 0.90 fibers per liter.
48. Sendai Environment Department. A Survey of the Amount of Hazardous Material Content in Areas Flooded by the Tsunami Has Been Conducted [in Japanese] [press release]. Sendai, Japan: Environment Management Section, Sendai Environment Department (28 Apr 2011). Available: <http://tinyurl.com/3sjxl4r> [accessed 9 Jun 2011].
49. Japan Society of Material Cycles and Waste Management. Chemical Characteristics of Tsunami Sludge Samples Collected in Sendai, Second Report: Oil Content and POPs [in Japanese]. Tokyo, Japan: Disaster Waste Management and Reconstruction Task Team, Japan Society of Material Cycles and Waste Management (19 Apr 2011). Available: <http://tinyurl.com/3b958dl> [accessed 9 Jun 2011].
50. Japan Society for Material Cycles and Waste Management, "津波堆積物の化学的性状について," supplemental material in "津波堆積物処理指針 (案)," published online 5 July 2011.
51. Tests were conducted only at limited locations - for instance, at two locations in Kesennuma, four in Minamisanriku-cho, and twelve in Ishinomaki - leaving open the possibility that some "hotspots" were not found.
52. Mitsui Co., Ltd, 25 July 2011, "三井物産環境基金 2011年度 復興助成 (第1回締切分) 「活動助成」助成案件一覧" (http://www.mitsui.com/jp/ja/csr/contribution/fund/pdf/a_110714_03.pdf)
53. Asahi Shinbun July 8 「がれき撤去やっと35% 被災3県、焼却施設も未整備」2011 (accessed at <http://v.go-iwate.org/?p=4412>).
54. Bird WA. Firsthand observation,

- Ishinomaki and Minamisanrikucho, Miyagi Prefecture (10–14 Apr 2011).
55. Industrial Safety and Health Act of 1972 (Japan). Article 22, Article 28-2 (1), Article 59 (1). Act No. 57 of 8 Jun 1972. Lawyer Naoki Ikeda said that case law has established that simply providing personal protective equipment or instructing workers to use it is not enough; the employer also needs to make clear the potential health consequences of not using the equipment.
56. Ministry of Health, Labour and Welfare. Important Notes for Safely Handling Debris in the Disaster Area [in Japanese] [press release]. Tokyo, Japan:Health and Safety Division, Labor Standards Department, Ministry of Health, Labour and Welfare, Government of Japan (22 Apr 2011). Available: <http://tinyurl.com/42hsaav> [accessed 9 Jun 2011].
57. Ministry of Health, Labour and Welfare. 70,000 Additional Respiratory Masks for Reconstruction Work Following the Tohoku Disaster Distributed to Labour Bureaus [in Japanese] [press release]. Tokyo, Japan:Health and Safety Division, Labor Standards Department, Ministry of Health, Labour and Welfare, Government of Japan (11 Apr 2011). Available: <http://tinyurl.com/3vdl4ge> [accessed 9 Jun 2011].
58. Miyagi Labour Bureau. Regarding the Implementation of Safety and Health Patrols at Debris Cleanup Sites in the Disaster Zone [in Japanese] [press release]. Sendai, Japan:Miyagi Labour Bureau, Government of Japan (27 Apr 2011). Available: <http://tinyurl.com/4xgvt9d> [accessed 9 Jun 2011].
59. Fukushima Labour Standards Bureau. Results of the Safety Patrols Carried Out at Debris Cleanup Sites [in Japanese] [press release]. Tomioka, Japan:Fukushima Labour Standards Bureau (27 Apr 2011). Available: <http://tinyurl.com/42wxsu6> [accessed 9 Jun 2011].
60. Information on handling disaster waste containing PCBs and asbestos was distributed to prefectural governments on 3.19.11. Municipal governments were also instructed to inform disaster victims about proper asbestos measures on 4.5.11. Ministry of the Environment (5.9.11)東日本大震災について (Regarding the Tohoku Disaster).http://www.env.go.jp/jishin/taio_u1105091700.pdf (retrieved 5.9.11)
61. NIEHS. NIEHS Response Training Tool. Controlling Hazards During the 2011 Earthquake and Tsunami Response. Research Triangle Park, NC:National Institute of Environment Health Sciences (2011). Available: <http://tinyurl.com/3hvbcsx> [accessed 9 Jun 2011].
62. Bird WA. Interviews with Goto Shiichiro, Japan National Council of Social Welfare, an umbrella organization coordinating volunteer work in the Tohoku region (26 Apr 2011), and Misuzu Asari, assistant professor at Kyoto University's Environmental Preservation Center, who has been spent extensive time in the disaster area and is now creating a manual for volunteers involved in the cleanup (30 Apr 2011).
63. Fukushima to Check Internal Radiation Exposure. NHK (Japan Broadcasting Corporation) (2 Jun 2011). Available: <http://tinyurl.com/4yp422o> [accessed 9 Jun 2011].
64. Debris Disposal Poses Problems for Quake-Affected Areas. Asahi Shimbun (1 May 2011). Available: <http://tinyurl.com/3rnnjjc> [accessed 9 Jun 2011].
65. 53. Ministry of Health, Labour and Welfare. Notice Regarding Tetanus [in Japanese]. Tokyo, Japan:Ministry of Health, Labour and Welfare, Government

- of Japan (11 Apr 2011). Available: <http://tinyurl.com/3hpdwv5> [accessed 9 Jun 2011].
66. Pritchard J, Kageyama Y. Nuclear Plant Downplayed Tsunami Risk. Associated Press via ABC News, Money section (27 Mar 2011). Available: <http://tinyurl.com/4ybn5wq> [accessed 9 Jun 2011].
 67. Koh Y. U.S. Criticized Tokyo's Nuclear Plan. Wall Street Journal, online edition, Business section (9 May 2011). Available: <http://tinyurl.com/3qe735x> [accessed 9 Jun 2011].
 68. Onishi N, Belson K. Culture of Complicity Tied to Stricken Nuclear Plant. The New York Times, online edition, Asia Pacific section (26 Apr 11). Available: <http://tinyurl.com/3kqm3za> [accessed 9 Jun 2011].
 69. Nuclear Experts Say Fukushima Accident Was Avoidable. Asahi Shimbun (23 Apr 2011). Available: <http://tinyurl.com/3momq23> [accessed 9 Jun 2011].
 70. FEMA. NRF Resource Center [website]. Washington, DC: Federal Emergency Management Agency, U.S. Department of Homeland Security. Available: <http://tinyurl.com/3do75zw> [accessed 9 Jun 2011].
 71. OSHA. Training Marine Oil Spill Response Workers under OSHA's Hazardous Waste Operations and Emergency Response Standard. OSHA 3172. Washington, DC: Occupational Safety and Health Administration, U.S. Department of Labor. Available: <http://tinyurl.com/2flrlyx> [accessed 9 Jun 2011].
 72. See, for example, the work of the Louisiana Bucket Brigade in response to ongoing oil refinery and petrochemical plant emissions, fenceline communities, and the Deepwater Horizon disaster: Louisiana Bucket Brigade [website]. New Orleans, LA: Louisiana Bucket Brigade (updated 9 Jun 2011). Available: <http://tinyurl.com/3a8ylsy> [accessed 9 Jun 2011].
 73. EPA. Green Chemistry [website]. Washington, DC: U.S. Environmental Protection Agency (updated 6 May 2011). Available: <http://tinyurl.com/6bhvudz> [accessed 9 Jun 2011].
 74. Center for American Progress, "Water utilities that have converted from extremely hazardous substances," 2 March 2010 [accessed 10 August 2011].