The Institute of Resilient Communities

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Abstract Resilience is the key to a prosperous global and modern society; Efforts to mitigate physical damage, economic loss, and to protect social and political infrastructures in response to catastrophic events, such as a nuclear accident or a natural disaster, are essential for communities to survive and thrive in the aftermath of such incidents. The 2011 Fukushima Dai-ichi nuclear power plant accident serves as an example of the risks associated with advanced technologies and the need to minimize physical as well as psychological effects on local and global communities. Other examples can be found reflecting the misperception of risks including concerns associated with vaccination or genetically modified organisms. While we have to recognize the risks associated with the development, implementation, and utilization of advanced technologies, we also have to recognize that the impact of not adopting them can have much more detrimental effects to individuals, communities, and even societies. We have established the Institute for Resilient Communities in Berkeley, CA in collaboration with Japanese partners to address the needs for better scientific and technological capabilities to assess, predict, and minimize the impact of disruptive events in the future and to enhance the understanding of associated risks to the public. While the initial focus resides in radiological resilience and is closely related to the events in Fukushima more than 5 years ago, the goal is to establish a broader framework for researchers, educators, and communities to enhance resilience locally and globally together.

Keywords Resilience · Communities · Radiological and nuclear accidents · Real and perceived risks of nuclear radiation and advanced technologies · Radiological resilience

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1 Introduction

The Institute for Resilient Communities (IRC) is dedicated to providing tools that can be deployed to enhance resilience in communities locally and globally. The goal is to minimize the impact associated with sudden or long-term changes induced by human actions or natural disasters or a combination of both. To achieve this goal, the IRC combines science, technology, education, and outreach and involves academic and educational institutions as well as communities in an international, multi-disciplinary, and multi-cultural context. It offers a framework for research, education, and community involvement to minimize the physical and psychological impact of future disruptive events and development and a forum for dialogue among researchers, educators, decision makers, and communities.

2 The Concept of Resilience

The term resilience has become widely used over the last 15 years, specifically after the terrorist attack on 9/11/2001 with slightly different definitions and interpretations [1, 2]. According to dictionaries, such as Merriam-Webster [3], resilience is defined as the ability to recover *after* a shock or deformation, the latter specifically in a mechanistic context. Sometimes, resilience is not only associated with the ability to recover after an event but also with actions to reduce the probability that a devastating event will occur (e.g. with the goal of avoiding or eliminating the possibility for incidents *before* they happen) [4]. Yet, others associate resilience with robustness or resistance to minimize or absorb the impact of an event, specifically in the context of resilience engineering with the focus on limiting the damage to infrastructure *during* the event [5]. In the following discussion and reflecting the goals of the Institute for Resilient Communities, we focus on the process to enhance capabilities to minimize the impact during and support the recovery after an unexpected event [6, 7]. This is similar to President Obama's statement describing resilience as "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies" [8]. While it is paramount to minimize the probability for an event to occur or to enhance the robustness of systems, catastrophic events with potentially devastating consequences—whether induced by nature or by actions or inactions by humans—will occur in the future. Resilience is a complex concept as it does not only include science and engineering to minimize the impact and to accelerate the recovery—ideally to a better state than before—but even more importantly, the concept embodies societal and educational components. Resilience efforts need to actively involve communities ranging from the local to the global scale, as communities need to be the drivers of actions to enhance their resilience and their ability to withstand and to recover more effectively. The goal of enhancing resilience is not to ultimately reduce resources for communities assuming that a state of sufficient resilience has been achieved. To the contrary, resilience implies a dynamic adaption to our ever-changing world, whether driven by environmental, technological, societal, health, or other causes.

The concept of resilience often appears provocative to the public, as it implies the possibility for more disruptions or accidents to happen. However, this is exactly what has to be realized: the fact that there is a finite probability for events with potentially disastrous consequences to happen. We need to enhance our resilience in order to be better prepared so we can minimize the physical and "measurable" impact as well as the psychological and emotional health impact. Only an informed public and educated decision-makers are able to provide an effective response to a disruption. The necessity for a better-informed public on advanced technologies or more broadly for a "technologically literate citizen" is not new [9]. As we can see, for example, from the events associated with Fukushima, in the discussion about vaccinations or genetically modified organisms (GMOs) the public, particularly in the United States but also globally, is susceptible to a perceived risk, rather than a factual risk. Unfortunately, the concept of risk is not well understood in the public and therefore, any discussion about risk is dominated by the potential impact of an event, rather than both the impact and the probability of an event. As a matter of fact, the likelihood for a disastrous event to happen is often neglected. The misperception of the concept of risk in the public is compounded by the fact that the potential impact can easily be used in the media to capture attention and increase readership. In addition, social networks are becoming one of the main venues for communications and distribution of information without any review and vetting of information. The fact that social networks operate instantaneously does not help conventional media to convey information that has been vetted and therefore, is always delayed. The delayed release of vetted information by conventional means also increases the potential for early spread of misinformation, which can be difficult to combat after the fact.

Regarding the contentious issue of GMOs, the risk of potential side effects overwhelms the discussion about the benefits in the public. While there is no scientific evidence supporting any claims of detrimental side effects of GMOs in the modification of approved food [10, 11], social media is dominated by claims of disastrous effects on animals and human consumers. Not only is a large portion of the animal feed in the US already genetically modified [12] without any obvious effect, GMOs need to play a critical role in addressing the enormous and expanding malnutrition in many developing countries specifically in Africa or India [13]. The development and utilization of vaccines have prevented devastating epidemics decimating whole communities and regions in the past. While vaccination is associated with a small health risk, this risk is insignificant in comparison to the risk of foregoing vaccinations. Recent increases in measles epidemics in the US reflect the emerging challenges by experts to convince the public about the benefits vs. the risk associated with vaccination [14].

The opposition to GMOs or vaccination is largely driven by the misperception of risk, as the general public often overestimates the detrimental effects and underestimates or is not aware of the benefits and the effects of not adopting these technologies. GMOs have another challenge in that it is a new and advanced technology that citizens have no exposure to or experience with. Therefore, the general public is not able to rationally anticipate the consequences, thereby adding GMOs as an example of the impacts of the fear of the unknown. The discussion of nuclear radiation, radioactivity, and ultimately nuclear power encounters a similar challenge. Radiation and radioactivity are largely misunderstood concepts in our society, resulting in highly charged discussions and decisions driven by emotions. The Fukushima Dai-ichi Nuclear Power plant accident, which happened as a consequence of the Great-Eastern earthquake in March 2011 and the subsequent tsunami, serves as an important example in which the psychological health effects have been substantial while the actual health effects due to the feared radiation remains minimal. We will discuss the need to enhance the radiological resilience to events like this in more detail in the next section, with the focus on our work in Berkeley and Japan and in an increasing number of other locations around the world. The global expansion reflects the need to enhance resilience—here specifically radiological resilience—globally, as the concept of radiation is not well understood and continues to evoke fear around the world. In addition, any event associated with the actual or potential release of radioactivity will be broadcasted instantly around the world through the social media networks, which may cause mass panic. It is worthwhile to mention that any large release of radioactivity will have an effect globally: First, due to the actual physical transport and second, due to the instantaneous communication through electronic and social media. As discussed above already, this is not only true for radioactive materials but also for viruses or bacteria, although the physical transport of viruses and bacteria will be slower as the “transporter” is not expected to be the atmosphere such as the effective jet streams across the world, but people and goods traveling across the world.

3 The Challenge Associated with Fukushima as Example

The events at the Dai-ichi nuclear power plant in Fukushima, Japan, in March 2011 have highlighted the need to enhance the resilience to radiological and nuclear events. The incidence and the associated large releases of radioactive materials had and still have an enormous societal and economical impact in Japan and globally. Although no casualties and health effects have been and likely will be attributable directly to radiation, these events have manifold and substantial impact on local communities and have provoked ongoing anxiety and concerns globally.

In order to minimize the impact of these and possible future radiological incidents, technologies and scientific understanding have to be enhanced and equally important, the understanding of nuclear and radiological matters in the public. An important reason for concerns and anxiety in local and global communities can be found in the lack of knowledge and accessible information about radiation and the lack of clear and transparent communications. As a result, confusion, misinformation, and conflicting statements from the government or scientists, as was the case after the Fukushima Dai-ichi nuclear power plant, can cause public distrust of the authorities and potentially of the scientific community. In addition, more effective technologies are required in combination with better scientific models to assess and predict the distribution and transport of radioisotopes in the environment and ultimately, to understand the transport into and minimize the impact onto the biosphere.

The events in Fukushima underscore the necessity for advancements in science and technology and improved communication with the public, and provide a unique opportunity to address both. Currently, local communities and global societies are ill-equipped to prepare for and respond to radiological events and the impact of perceived risks associated with nuclear and radiological incidents. Major releases of radioactivity will have a global impact for two reasons: (1) The radioactive materials can be transported globally quite effectively as has been observed after Chernobyl or Fukushima or previously with nuclear weapons testing; (2) Any event related to the releases of radioactivity will end up as headlines in the global and social media as it is seen as a rare, newsworthy incident, and will be—in most cases inaccurately—associated with a significant health impact. Both aspects will cause increased concerns and fear world-wide, which can only be addressed by an enhanced understanding of radiation through improved scientific literacy and public communication, as well as a better understanding of the associated risk for environmental, biological and health effects. Furthermore, the perceived risk and perceived danger of radiation will continue to hamper public acceptance of nuclear power, which has the potential to contribute to the effort to combat climate change by providing another carbon free energy source necessary to meet the increasing future energy demands while reducing the global CO_2 footprint.

4 Combining Research, Education and Outreach, and Communities—The Institute for Resilient Communities

In order to address the above-described need to enhance community resilience, we have established the Institute for Resilient Communities with the initial focus on radiological resilience, reflecting our activities in response to the Fukushima Dai-ichi Nuclear Power Plant accident. Our Institute-related efforts are composed of research, education and outreach, and community involvement. We briefly discuss each component.

4.1 Outreach and Education—The Berkeley RadWatch and DoseNet Projects

After the releases of radioactive materials on and shortly after March 15, 2011 from the badly damaged Fukushima Dai-ichi nuclear power plant, a team of UC Berkeley graduate and undergraduate students set up sample monitoring stations (which were later upgraded with more sophisticated instrumentation) to collect rain water and air samples on the roof of Etcheverry Hall on the UC Berkeley campus. Subsequently, other environmental as well as a wide range of local food samples were measured utilizing state-of-the are radiation detection equipment available at UC Berkeley and LBNL. The goal of this activity was two-fold: (1) To study the characteristics, such as type and quantity, to determine whether measurable amounts of radioactive materials that we could associate with the releases in Fukushima could be detected (including monitoring for the gradual disappearance of measurable materials); (2) To make the results from the monitoring stations easily accessible and digestible to the general public and to engage the public in a dialogue about radiation and to put our findings in the context of the radiation we are exposed to naturally or electively on a daily basis.

The effort described above, as well as ongoing measurements conducted at UC Berkeley, are part of the Berkeley RadWatch project [15]. Within one week of the 2011 accident in Fukushima, we established a website, which hosted results and analysis, as well as a forum for discussion of the results. Responses to claims and results from other sources, in some cases, claims that were scientifically inaccurate or did not have any scientific basis, were also posted on the site. Since the start of this program in 2011, we have performed more than 1000 measurements with all data and results available at the website. Early in 2014, our team installed an automatic and near-real-time air monitor that provides activities of radioactive particulates captured in a filter mounted in front of a high-energy resolution high-purity gamma-ray spectrometer. This system represents a world-wide unique instrument as it continuously measures radioactivity in air with a state-of-the art and expensive gamma-ray spectrometer and provides the raw spectra and isotopic analysis every 15 min.

In parallel with the RadWatch project, we established the Kelpwatch project in collaboration with Steve Manley from California State University in Long Beach, CA [16]. The goal of this activity was to measure radioisotopes in marine kelp that is collected along the Pacific Coast of North America. Just as RadWatch monitored the arrival of radioisotopes from Japan in California via the jet stream within about 70 h after the releases, the main goal of Kelpwatch was to observe the arrival of radioactive materials that were released into the ocean in March 2011 and carried by the Pacific Ocean currents to the coast of California. Oceanographic transport models expected the appearance 2–4 years after the releases [17]. Kelp samples were acquired and analyzed during five collection periods at about 40 sites between February 2013 and May 2016. We were not able to measure Cs-134 in any sample. The Cs-134 radioisotopes can be used as strong evidence to originate from the Dai-ichi Nuclear Power Plant accident. This is in contrast to the observed Cs-137, which also originated from Fukushima but also from the above-ground weapons tests and has not disappeared yet due its 30 year half live. It is interesting to note that the Cs-137 concentration we observed in kelp was in the order of 0.2 Bq/kg for all samples and the limits for Cs-134 were 0.05 Bg/kg, indicating that most of the Cs-137 observed remains from the weapons test more than 50 years ago. Since these numbers do not mean much in general, we need to put them into the context of naturally occurring radioactivity. For example, the concentration of naturally occurring K-40 was about 4000 Bq/kg in these samples, a factor of 20,000 more then the Cs-137 observed. By utilizing a chemical preprocessing step and filtering large amounts of water, the Woods Whole Oceanographic Institution was able to measure Cs-134 off the Northern California Coast in water [18]. The observed concentration of 2 mBq/l is a factor 5000 less than the approximately 10 Bq/l of naturally occurring K-40 observed in the Pacific Ocean [19]. The ongoing releases of contaminated water off the coast of Japan resulted only in fairly small concentrations, even close to the harbor of the power plant. For example, the water concentration of Cs-134 in close proximity to the harbor of the Dai-ichi nuclear power plant is about 20 mBq/l, if detectable at all [19]. While the observation of Cs-134 in the water does confirm the transport of this isotope via ocean currents, it is significantly diluted spatially and temporally and—as expected and as with the other samples mentioned before—never posed a health risk to the public or the environment.

We are still continuing to conduct environmental and food sample measurements to-date, including measurements driven by requests from the public. This even includes materials from Europe with potential contamination from the Chernobyl accident more than 30 years ago. In addition to real-time air-sampling and sample measurements performed utilizing gamma radiation, the team set up alpha spectrometers that enable us to measure alpha particle decay in the same samples. The main goal of this activity is to measure naturally occurring alpha decay, specifically of Po-210. The fact that there is naturally occurring gamma radiation in the environment is not widely known, and the fact there is naturally occurring alpha-particle radiation is even less known. However, naturally occurring background radiation is part of the world we are living in and something that the general public should be aware, so any new information about radioactive contamination can be put into the proper context. It is noteworthy that the Po-210 measurements, particularly in fish, do dominate the radiation exposure, meaning the dose from Po-210 is larger than the dose due to K-40 [20]. This information should not lead to a decision to avoid eating fish, as we are exposed to Po-210 all the time as it is part of the radioactive decay chain starting from U-238. Radioisotopes such as U-238, Th-232, or K-40 have half-lives of billion of years and can be found everywhere in our universe resulting in some amount of radioactivity even in the smallest quantities of matter. In addition to the gamma-ray and alpha-particle monitoring performed in the RadWatch UC Berkeley lab, we have performed so-called neutron-activation analysis experiments which allow us to measure trace amounts of non-radioactive matter in our environment and food. Of specific interest are trace metals, such as mercury or arsenic, which can be commonly found in food and fish. In keeping with the RadWatch mission, the goal is not to make the public fearful of food or our environment, but to make them aware of the world we are living in and to ultimately put the observation and risks of radiation in a proper context. All this information is available online on our Berkeley Radwatch website [15].

In order to further enhance awareness of radiation and its properties, and to combine efforts to raise awareness with education and outreach, we have established the Berkeley DoseNet program [21]. This program consists of a sensor network that is being developed across high- and middle schools in the Bay Area as well as well UC Berkeley and other high schools and research institutions in Japan, South Korea, and Sweden. The sensors are equipped with a Raspberry-Pi computer and initially set up with a simple radiation dosimeter. These dosimeters are loaned to the local school partners and collected data is made available to the public on the Dosenet website in 5-min intervals. The DoseNet team is currently collaborating with participating teachers to develop projects that students can work on with the data collected, either with their school's local data or with the data available across the network. These projects have two objectives: (1) Allow the students to "see" radiation in our environment and to learn important properties of radiation, e.g. the fact that it varies spatially and temporally or that it can be shielded or reduced by increasing the distance; (2) Enable a better understanding and appreciation of fundamental concepts in science and engineering such as uncertainties associated with observations and measurements, statistics and probability, and ultimately, risk. As the concept of risk is becoming ever more important in our modern and technological driven global society, it needs to be better understood by the public. The first objective addresses specifically the fear of radiation in the public as it can not be recognized with human senses. The second objective addresses the need to enhance more broadly the science and technology literacy of citizens. In parallel to expanding geographically, we are planning to upgrade and complement the radiation sensors with better radiation detectors and other sensors. We are in the process of integrating recently developed pocket-sized CsI(Na) scintillator-based detectors that enable us not only to register radiation, but also to measure the energy of radiation, e.g. to see the "color" of nuclear radiation. The "color" tells us about the origin and the type of materials, specifically the isotope, that emitted the radiation. Complementary sensors will include air-particulate and CO_2 sensors that will become part of the sensor package. We encourage schools to add digital weather stations to the sensor package, as it is quite interesting to study correlation between weather patterns and the quantities observed with the sensor package.

4.2 Science and Technology—Assess, Predict, and Minimize the Impact of Radiological Contamination

Our research within the context of radiological resilience at LBNL is currently engaged in four different scientific and technology domains, which address current needs in the evacuated areas in Fukushima Prefecture to ensure the safety of the population when they return and in the future. As of January 2016 about 85,000 people are still evacuated and many, particularly older people want to move back to their homes and communities [22]. The research areas we are currently pursuing in collaboration with scientists from JAEA aim at more effective means to map the contamination, at a better understanding and improved predictive power of environmental transport models, enhanced understanding and measurements of internal human radiation dose, and the removal of contamination from soil. While the focus initially is on the most abundant contaminant left (cesium) in the environment of Fukushima, the knowledge gained and technologies developed will provide significantly improved means in the aftermath of any radiological event in the future that is associated with the release of radioactive materials. The environment in Fukushima Prefecture represents a very different environment than, for example, the region of Chernobyl, as Fukushima Prefecture consists of large portions of forests and mountains with significant precipitation year-round, causing continuous changes in the contamination patterns. Figure 1 summarizes the four areas of research and their relationships. These activities are coordinated with the substantial efforts by the JAEA in Japan.

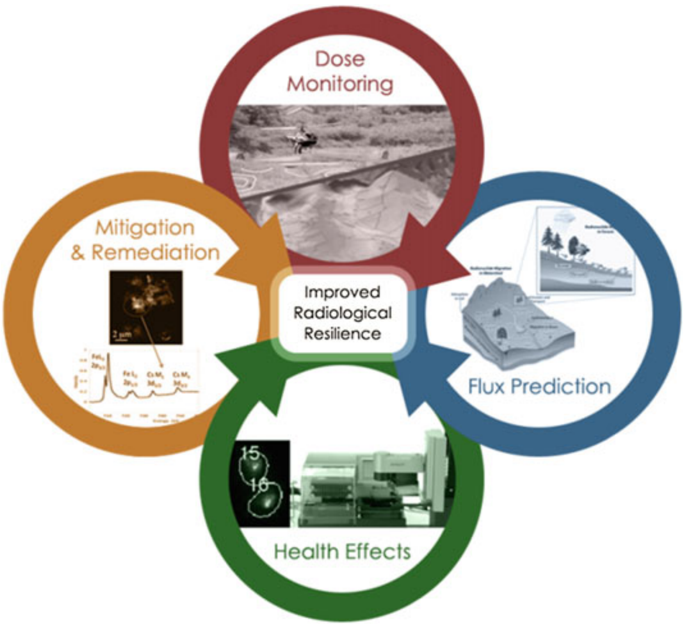

Fig. 1 The four main research areas being pursued initially as part of the new Institute for Resilient Communities. The goal is to enhance the effectiveness in monitoring and predicting radiological transport in the environment, to better understand and minimize the impact of radio-isotopes in the biospheres, particularly humans, and the remediation of these radiological materials, particularly cesium

4.3 Status and Path Forward

The aforementioned education, outreach, and research activities are the central pillars for the Institute for Resilient Communities. Based on these established activities we will expand our outreach and research activities locally in Berkeley and with our research and community partners and organizations in Japan and beyond. Reflecting the need to work with local communities we are actively collaborating with cities, such as Berkeley in the U.S. and Koriyama in the Fukushima Prefecture in Japan.

Complementary to the research, we will continue the RadWatch project's efforts, including near-realtime air monitoring and measurements of environmental and food samples, and Kelpwatch, as part of the outreach and educational efforts. As before and reflecting the importance of transparency in any of our activities to maintain public trust, we will publish all our measurements, procedures, and findings.

5 Summary

Recent events associated with the releases of radioactive materials and the recognition of the possibility of events that are associated with the release of radioactive materials to happen in the future represent major challenges for advanced and global societies. Radiological or nuclear events due to accidents have and will have an enormous socio-economical and political impact on local and global communities. While it is possible that such an event may have some health effects due to radiation, the psychological impact will be significant, as observed in Japan. While it is paramount to enhance the safety and security of the currently operating and future nuclear power plants, it is also critical to enhance means in responding and recovering from a possible event to minimize the impact of such events, i.e. to increase the resilience to such events.

The Institute for Resilient Communities addresses this need by combining natural and social sciences, technology and engineering, and education and outreach, and involves local communities, all in a global context. It addresses the need to improve the scientific understanding of the causes and impacts of such events. The education and outreach aspect aims to minimize the psychological effects through a better-informed public. While the initial focus will be on radiation, the goal is to establish programs to enhance science and technological literacy more broadly, including basic concepts in science and engineering. Data are collected and made available to recognize and appreciate the world we are living in, particularly the world we cannot see or physically feel. Local communities and schools are being involved to effectively introduce these concepts to the public and into schools. By providing such a framework, the Institute for Resilient Communities is a trusted resource to the public, media as well as decision makers, essential in the response to a radiological or nuclear event to minimize the effect and speed-up the recovery, i.e. enhancing resilience.

References

1. L. Labaka et al., Homeland Security & Emergency Management **10**(1), 289–317 (2013). doi:10.1515/jhsem-2012-0089
2. J.H. Kahan, Resilience redux: buzzword or basis for homeland security. Homel. Secur. Aff. **11**(2) (2015), https://www.hsaj.org/articles/1308
3. http://www.merriam-webster.com/dictionary/resilience
4. T.J. Vogus, K.M. Sutcliffe, Organizational resilience: towards a theory and research agenda, in *IEEE International Conference on Systems, Man and Cybernetics*, pp. 3418–3422 (2007). doi:10.1109/ICSMC.2007.4414160
5. L. Labaka et al., Enhancing resilience: implementing resilience building policies against major industrial accidents. Int. J. Critic. Infrastruct. **9**(1/2), 130–147 (2013)
6. M. Bruneau et al., A framework to quantitatively assess and enhance seismic resilience of communities. Earthq. Spectra **19**, 733–752 (2003)
7. J.H. Kahan et al., An operational framework for resilience. J. Homel. Secur. Emerg. Manage. **6**(1), 1–50 (2009)
8. Executive Office of the President, Presidential Policy Directive-8 (PPD8), February 2011, Washington, DC, 6
9. G. Pearson, A.T. Young, Technically speaking: why all Americans need to know more about technology. Committee on Technological Literacy, National Academy of Engineering; National Research Council (2002). ISBN: 0-309-51013-9
10. C. Snell et al., Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: a literature review. Food Chem. Toxicol. **50**, 1134–1148 (2012)
11. Committee on “Genetically Engineered Crops: Past Experience and Future Prospects”. Board on Agriculture and Natural Resources; Division on Earth and Life Studies; National Academies of Sciences, Engineering, and Medicine. doi:10.17226/23395 (2016). ISBN 978-0-309-43738-7
12. A.L. Van Eenennaam, A.E. Young, Prevalence and impacts of genetically engineered feedstuffs on livestock populations. J. Anim. Sci. **92**(10), 4255–4278 (2014). doi:10.2527/jas.2014-8124
13. D.H. Freeman, The truth about genetically modified food. Sci. Am. (2013)
14. M.S. Majumder et al., Substandard vaccination compliance and the 2015 measles outbreak. JAMA Pediatr. **169**(5), 494–495. doi:10.1001/jamapediatrics.2015.0384
15. https://radwatch.berkeley.edu/
16. https://kelpwatch.berkeley.edu/
17. V. Rossi et al., Multi-decadal projections of surface and interior pathways of the Fukushima Cesium-137 radioactive plume. Deep-Sea Res. I **80**, 37–46 (2013)
18. Woods Hole Oceanographic Institution, Fukushima Radioactivity Detected Off West Coast (2014), http://www.whoi.edu
19. Nuclear Regulatory Agency, Japan, Monitoring information of environmental radioactivity levels. Distribution map of seawater radioactivity around TEPCO Fukushima Dai-ichi NPP (2015), http://radioactivity.nsr.go.jp/en/
20. N.S. Fisher, “Evaluation of radiation doses and associated risk from the Fukushima nuclear accident to marine biota and human consumers of seafood. Proc. Natl. Acad. Sci. (2013). doi:10.1073/pnas.1221834110
21. https://radwatch.berkeley.edu/dosenet/map
22. http://www.japantimes.co.jp/news/2016/01/09/national/fukushima-nuclear-evacuees-fall-100000/#.V9yRDJMrLUI