THE SAFECAST REPORT

VOLUME 1 - MARCH, 2015

www.safecast.org

So, what is The Safecast Report?

Now, at the 4th Anniversary of Safecast, we're excited to present the first volume of THE SAFECAST REPORT. But, why a report? And why now? When we started Safecast in March 2011 in the aftermath of the Fukushima Nuclear disaster, our prime questions were "What are the radiation levels?" and "Is it safe?" These concerns became and today are still the major drivers for the Safecast project.

This has led us on a journey in which Safecasters around the world have developed open hardware, open software, visualizations, methods, and community to answer these basic questions. We now boast a host of mobile radiation sensors worldwide and have amassed the largest open data set of radiation measurements. However, along this journey we've learned a lot, seen our limitations, seen the strengths of others, gotten requests to do more, and gotten many more questions we struggled to find answers for, and this has slowly refined our mission. Though we started with measuring radiation levels in the streets of Fukushima, our mission has expanded to the wider quest for more open data about the environment everywhere. To do so we've reached out to all corners of society: citizens young and old, companies, educational institutions, and local governments. We've made it our mission to make everything we do "open," to encourage others to participate in our projects, and to be inspired by the Safecast Code (http://blog.safecast.org/2014/09/safecast-code/).

As we've collected and shared more data, we've been better able to gauge the true scale of the problems we've tackled, have gotten a better idea of what else is out there, seen what is working, and more importantly areas where we could do better. In this report, we want to share what Safecast is doing today, in Japan and globally. We also want to share what we have learned from other projects, studies, and initiatives. Importantly, we also want to take the opportunity talk about where we feel others, specifically governments, universities, and companies, can do more to make their data sets openly available and to recognize the importance of third party verification by open, citizens-powered projects like Safecast.

Why now? A lot has happened in the past 4 years. As the Safecast Project has grown, more and more people both inside and outside of Japan have decided to take part, and some have been inspired to start their own citizen science projects. People are seeking answers to many questions but often lack access to the data they need, or find it's in a proprietary format, and we have evangelized open data as the best solution for most data projects, especially those that seek to encourage citizen involvement. When we hear of governments or organizations gathering large amounts of data about radiation, pollutants, climate change, or demographics, to mention a few areas, we always urge them to make their data open. Unfortunately few do.

The Fukushima Daiichi nuclear disaster is far from over. Four years may seem like a long time, but the half-life of Cs-137 is many times longer than this, and it will take generations before the radiation levels are really back to normal. Over the past few years, The Internet of Things has become a major buzzword, and despite the hype, the technology and applications that are making it possible are helping usher in the age of open data and citizen empowerment. With the Safecast Report we want to show what we're doing now and what others are doing that we feel are worth sharing, and hopefully will inspire others to participate in this exciting project, to learn, and to take action.

We have split the Safecast Report in two sections: an update about the Safecast project itself, and an in-depth examination of the status of measurement and monitoring at the Fukushima Daiichi plant and in the wider environment, as well what we know about radiation in food and in people's bodies, and the consequences for the health of individuals and communities. We intend to issue updates to the Safecast Report twice a year, and plan to add information about air and water pollution in future installments. We also welcome your feedback and suggestions, as well as your questions.

None of this would have been possible without the support of our many passionate and generous volunteers!

THANKS!!!

THE SAFECAST REPORT TEAM:

Azby Brown, Pieter Franken, Sean Bonner - March 2015

An updated and commented version of this report can be found online at:

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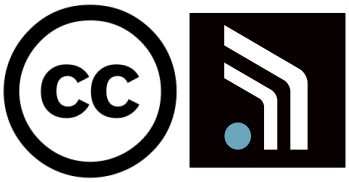
www.safecast.org



This report is not intended to be all things to all people, rather we expect it to be some things to many people. Contained within is a collection of information about Safecast and our activities, as well as the larger situation in Japan. Not everything in here will be interesting to everyone, but we're tried to anticipate and reply to the most burning questions.

EXECUTIVE SUMMARY

Part 1: SAFECAST PROJECT

1.1 Safecast Code

In 2014 we took a bold move and published the Safecast Code 1.0, which attempts to describe the Safecast project as a whole through a list of 10 attitudes that guide all of our efforts. You could call it our "code of conduct," something we wrote to remind ourselves when we start to drift what our goals are and what we should be doing. We try to measure up to the attitudes in this list and encourage others to do the same.

In addition:

— We strongly feel that data about our environment should be open, easy to access and easy to understand.

— A second opinion about environmental data has to be available. In the age of the Internet of Things, that voice can come directly from citizens.

— Official groups such as governments, universities, and companies should publish data about the environment under Creative Commons Zero (CC0) public domain designation and acknowledge the importance of a third parties to validate their own data against.

1.2 Mobile Radiation Measurement

Safecast volunteers have been collecting radiation data using bGeigie mobile radiation sensors since April 2011. Over 600 bGeigies have been built, and have collected over 27,000,000 measurements. These cover almost all Japanese roads, with many areas repeatedly measured over time. We now have data from every continent, and more 65 countries. The Safecast dataset also now includes data from far corners such Sudan, Iraq, Antarctica and the Marshall Islands and sites of interest such as Chernobyl. The current work horse for mobile radiation measurement is the bGeigie Nano Kit of which more than 400 have been deployed since it was released it in mid 2013.

1.3 Stationary Radiation Measurement

In March, 2015, realtime.safecast.org launched. This new initiative is focused on deploying stationary radiation sensors in Japan and globally. Our goal is to deploy 25 fixed sensors in Fukushima in 2015, to form an independent real-time network. We will also continue to expand this network overseas.

1.4 Air Pollution Measurement

While the primary focus of Safecast until now has been radiation measurements, we've always intended for the project to grow to include other environmental data. We now have working prototypes of a modular Safecast air quality device, based on the bGeigie form factor, which can eventually be fused with other sensors.

1.5 Open Data (aka The Safecast API)

SAFECAST tries to set an example of openness in how we gather and present our data, and to demonstrate what the wider benefits of easy access to open data are for society as a whole. We're convinced that the more open data is, the more useful it becomes.

In order to clarify our stance and encourage others to adopt similar policies, we recently posted a detailed FAQ about our openness and access features.

1.6 Data Visualization

Over the last year the online Safecast map has seen a tremendous amount of evolution and improvement. This has meant many new features and great speed improvements across the board. For iOS devices, version 1.7.1 of the Safecast app was released in March, 2014. The Safecast app for OS X was also introduced in July 2014, based upon the tile engine used by the mapping features of the iOS app. It provides a full desktop experience with the same dynamic and offline-capable functionality as the iOS app.

1.7 Activities

From the start, we've considered events and activities to be an important part of communicating what we are doing, building our community, and training our volunteers. We frequently hold workshops, hold hackathons, give talks, and participate in public symposia. We were also happy to be invited to speak at important symposia in Japan and overseas, including an IAEA expert meeting and a disarmament and non-proliferation conference at the VCDNP, both in Vienna, as well as a public symposium in Tokyo jointly organized by United Nations University and UNSCEAR.

1.8 Outreach

We consider outreach and collaboration with universities and other academic institutions to be valuable community and skill builders. Ongoing and new collaborations include ones with MIT Media Lab, Keio University, Aoyama University, Kanazawa Institute of technology, and San Diego State University.

1.9 Press & Publicity

Contributing to media is an important activity for Safecast, as it allows our message to be propagated to a larger audience and also helps us to connect to new volunteers. Not only do we appear in articles, we also have become a source for journalists who want to learn about radiation, and we have spent countless hours with reporters to share what we know and connect them with relevant people and organizations. In the past year we have had significantly more prominent coverage from mainstream Japanese media, including and 20-part series in the Asahi Shimbun and a 30-minute documentary on NHK World.

1.10 Funding & Support

We continue to benefit from the generosity of donors such as the Shuttleworth Foundation, which is sponsoring key areas of our activity this year, including the SCC2015

conference, as well as past support from the John S. and James L. Knight Foundation. Many companies continue to provide contributions in kind as well. We express our sincere gratitude to all for this invaluable support.

1.11 Always Improving

If you see anything you think could be done better, needs fixing, or can be complemented, or if you simply want to help out or to contribute, let us know at info@safecast.org.

And if you want to learn how to make your data open and more useable (as a citizen, company, university, or government body), we're here to help.

Part 2: SITUATION REPORT

2.1- Issues at Fukushima Daiichi Nuclear Powerplant (FDNPP)

2.1.1—Decommissioning roadmap

Everything that is being done now and which will be done on site until the year 2020 is merely preparation for the really hard work of removing the melted core material. There is a roadmap, and TEPCO is basically on schedule so far, but it gets much harder from this point forward. There is regulatory oversight, but we don't think it's intrusive enough.

2.1.2— Spent fuel pools

Despite loud portents of doom,TEPCO succeeded in safely removing all of the spent fuel from Unit 4 in December, 2014. This unit had the most fuel to remove, but the remaining three units will almost certainly be harder. The last are due to start being emptied in 2017. This fuel needs more secure long-term storage than in the common pool onsite, though there's really no place else to put it yet.

2.1.3—Water problems

We hear a lot about the water problems at the Daiichi site because they're serious and are an obstacle to starting the other work which needs to be done. If we could see the water that's causing the most trouble things would be a lot easier, but we can't because it's underground. The difficulty of the water problems has forced TEPCO to think ambitiously and innovatively, and appears to be advancing technology in some areas. But most of the other leaks which make the news (because they can be easily detected) have very low-tech, easily preventable causes.

2.1.4—Radionuclide removal systems

The systems TEPCO uses for removing radionuclides from water onsite started as an unreliable hack, but have gradually grown and become more stable and sophisticated. It's an incremental learning process that we're very familiar with. TEPCO has spliced together several different systems to make it possible to scale up and add new capabilities, and initiate new technological developments. The overall system seems to be performing well now, but there are still several weak points where breakdowns could lead to even more delays in processing all the water that needs to be treated.

2.1.5— Groundwater problems

Briefly put, the planned solution to the extremely challenging groundwater problem at the Daiichi site is an ambitious series of underground dams made of ice (frozen soil), and dozens of pumps. The pump part would be straightforward if the water wasn't radioactive. All the eggs are in this basket, and we haven't heard of a plan "B" in case it fails. Unless the groundwater problem is solved, it won't be possible to carry out the next steps to prepare from removing the melted fuel.

2.1.6— Melted fuel removal

This has only really been done once before, at Three Mile Island, where melted core removal was completed in 1990, so there are not many people with experience to call on for assistance. The job is too big for any one company to tackle, so a new, well-funded research institute has been established to incubate the kinds of technologies that will be necessary. The process will require decades.

2.2- Evacuees and Returnees

Their lives are uprooted, and their grievances are immense and deep-seated. Much of their plight is rooted in hastily made decisions about where to draw lines between the evacuated and those who were allowed to remain -- assuming they wanted to, or would be financially able to leave if they didn't. At the moment, not many evacuees want to return to their abandoned home towns despite enticements from all levels of government, but quite a few who lived outside the evacuation zones have returned. Meanwhile a huge disparity in compensation has driven communities even further apart.

2.3- Environment and Decontamination

The radioactive releases to the environment from Fukushima Daiichi are unprecedented in many respects, but also comparable in many ways to releases from other accidents and from nuclear weapons testing. Radionuclides are both persistent in the environment and mobile, and it's of paramount importance to locate and track them as they disperse through the ocean and migrate into the soil and through watersheds, to know where to expect food species to be contaminated and by how much, and where the places where people live will require remediation, or even abandonment.

2.3.1 The land environment

Odd though it may seem to say it, it was fortunate that only about 20% of the radioactive releases from Daiichi ended up on land. Even that much has caused the displacement of over 160,000 people, and necessitated very costly remediation of farmland and living areas. Fortunately as well, most kinds of environmental radiation is not very difficult to detect and map. This is why SAFECAST exists.

2.3.1a Forests

About 70% of the fallout that fell over land ended up in forests, which will be impossible to effectively decontaminate, and where it will remain bioavailable to plants and wildlife for decades. Radionuclides have essentially hijacked the watershed, turning it into a cesium delivery system (while delivering smaller amounts of other nuclides as well). Fortunately researchers have a lot of experience tracking them in these environments.

2.3.1b Decontamination progress, plans, effectiveness

The area needing to be decontaminated is huge. When we investigated the effectiveness of the techniques being used two years ago, we concluded that it was only partly effective, and that in many situations it made more sense to wait for natural radioactive decay to take its course. In some cases decontamination appears to be what we call an "optical" solution -- to show that efforts are being made. But much of the time it can make a big difference in radioactive exposures and doses. Regardless, it's a management and communication nightmare, and we're not surprised many residents remain skeptical.

2.3.2 The Ocean

The radioactive releases to the ocean were huge, but not really unprecedented. Many teams of oceanographers have been tracking and sampling the nuclides as they make their way across the Pacific, and predictions they made two years ago about how long it would take the ocean "plume" to reach the coast of North America, and how much cesium would be in it when it got there, have proven to be very accurate. As predicted, the levels are very low, lower than in the 1970's for instance. But the plant is still leaking and major releases of contaminated water cannot be entirely ruled out. Meanwhile, the radioactive contamination on the seabed off the Fukushima coast has been mapped, and experts agree that only time will reduce the ongoing impact on marine species, including many dining table mainstays. Close monitoring of the ocean environment is extremely important and will continue to be for years to come.

2.4- Food

Keeping contaminated food off the market is essential for minimizing internal exposures to radiation. This risk is chronic because cesium and other radionuclides remain in the environment for years -- decades in many cases -- usually migrating deeper into the soil, and even if the problem appear to be controlled at some point, it is still present. The Japanese government quickly instituted a food monitoring program in March 2011, and in scale and comprehensiveness it has been unprecedented. Not everything is checked, however, which is why the appearance of dozens of independent, citizens-run food testing labs all over the country is extremely welcome. Also welcome are independent tests of actual meals being eaten by residents of Fukushima and elsewhere. While the relative paucity of tests for strontium remains a matter of concern, the independent tests tend to support official findings, that less that 1% of the food being produced in Fukushima has above-limit concentrations of cesium, and virtually none of this is finding its way onto the market. Farmers themselves deserve almost all the credit for this. The biggest food risks -- wild mushrooms and vegetables, and wild boar and other game -- are well known, and will continue to pose problems for years to come.

2.5- Health

The concern about health damage from radiation exposure, and particularly the vulnerability of children, has made it the single most contentious issue surrounding the Fukushima disaster. Health concerns are the reason people were evacuated, and prompted many families to mistrust official assurances and move away on their own. The problem is exacerbated by the fact that the most likely radiation-related diseases, such as cancer and leukemia, will not appear for years after the exposures, and will only be detected by large-scale, long-term monitoring. The government quickly got such programs up and running, and the results so far give cause for cautions optimism, but it is too early to tell, and inadequate transparency and poor communication have left many citizens suspicious.

PART 1: THE SAFECAST PROJECT UPDATE, MARCH 2015

Compiled by Pieter Franken (Japan ops) and Sean Bonner (Global ops)

The Safecast Project now spans numerous aspects of environmental measurement. To keep it simple, the key areas where we're active today are:

1. Safecast Code - what we stand for and how we (think) we do it
2. Mobile Radiation Measurement
3. Stationary Radiation Measurement
4. Air Pollution Measurement
5. Open Data (The Safecast API) - the open data store
6. Data Visualization: maps and apps!
7. Activities: workshops, hackathons, talks
8. Reach out: share, help and learn
9. Press & Publicity - highlights and coverage
10. Volunteers - Safecasters and where you can help
11. NPO, Funding & Contributions
12. Always Improving - disclaimers

1.1 Safecast Code

The Safecast Code

In 2014 we took a bold move and published the Safecast Code 1.0, which attempts to describe the Safecast project as a whole through a list of 10 attitudes that guide all of our efforts. You could consider it our code of conduct, for reminding ourselves of what are goals really are and what we should be doing. We try to measure up to the attitudes in this list and encourage others to do the same.

- ALWAYS OPEN – We strive to make everything we do transparent, public and accessible.
- ALWAYS IMPROVING -We can always do better so use agile, iterative design to ensure we're always refining our work.
- ALWAYS ENCOURAGING – We aim to be welcoming and inclusive, and push each other to keep trying.
- ALWAYS PUBLISHING - Results are useless behind closed doors, we try to put everything we're doing out to the world regularly.
- ALWAYS QUESTIONING – We don't have all the answers, and encourage continued learning and critical thinking.
- ALWAYS UNCOMPROMISING – Our commitment to our goals keeps us moving closer towards them.
- ALWAYS ON – Safecast doesn't sleep. We're aware and working somewhere around the world 24/7
- ALWAYS CREATING – Our mission doesn't have a completion date, we can always do more tomorrow.
- ALWAYS OBJECTIVE – Politics skews perception, we focus on the data and the questions it presents.
- ALWAYS INDEPENDENT - This speaks for itself.

These principles incorporate some of the guiding principles of Safecast co-founder Joi Ito <http://www.media.mit.edu/about/principles>. "Deploy or Die" and "The power of Pull" are two that resonate a lot with us.

We're on a mission

We're not saying that we're on a mission from God, but we do have something to say:

- We strongly feel data data about our environment should be open, easy to access and easy to understand
- A second opinion about environmental data has to be available. In the age of the Internet of Things, that voice can come directly from citizens
- Official groups such as governments, universities, and companies should publish data about the environment under Creative Commons 0 ("CC-0") licence and acknowledge the importance of a third parties to validate their own data against.

"The Safecast Report"

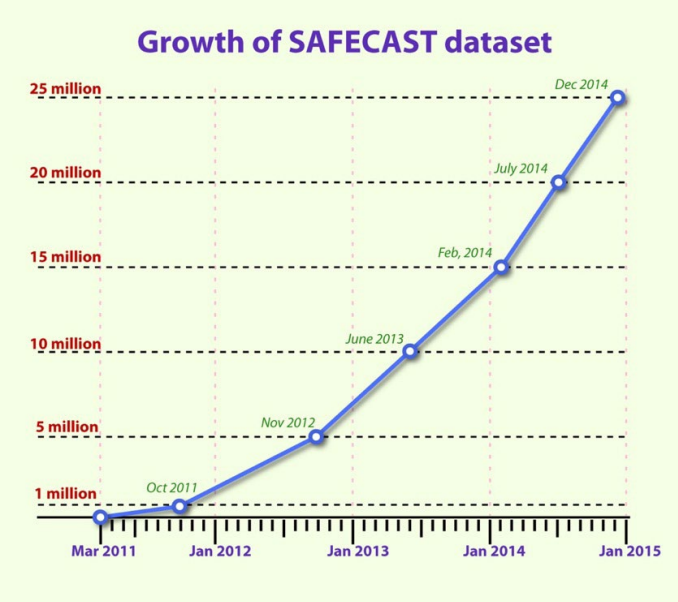
You are currently reading the first volume of The Safecast Report, which was published on March 22, 2015, as part of the Safecast Conference 2015 (#SCC2015). We plan to regularly update the report and publish it semi-annually in March and September. An online version, updated and commented, can be found at:

https://medium.com/safecast-report

The Safecast Measurement Method

For the coming year, one of our goals is to document the Safecast measurement method and answer many of the questions (and challenges) we have had concerning the method.

1.2 Mobile Radiation Measurement



The Safecast radiation measurement dataset contains over 27 million measurements as of March 2015.

Since April 2011, Safecast volunteers have been collecting radiation data using bGeigie mobile radiation sensors. As of March 2015, over 600 bGeigies have been built and have collected over 27,000,000 measurements. Almost all Japanese roads have been measured, with many areas repeatedly measured over time to prvide clear evidence of radiation level changes. Additionally, data has been collected from every continent around the world and more 65 countries including most of Europe and North America. The Safecast dataset also includes data from far corners including Sudan, Iraq, Antarctica and the Marshall Islands and sites of interest such as Chernobyl.

Hardware

The bGeigie Nano is the current workhorse of Safecast's radiation measurement efforts.

The current workhorse for mobile radiation measurement is the bGeigie Nano Kit, of which more than 400 have been deployed since it was released it in mid-2013. Previous generations of the bGeigie family include the bGeigie Mini, bGeigie Plus, the original bGeigie, and the one-of-a-kind xGeigie. We also designed, prototypes, and ultimately abandoned a bGeigie 3. Models prior to the bGeigie Nano were much more labor intensive to build and had a higher individual cost per unit. Creating the scaled-down - in both price and size - bGeigie Nano solved our device supply chain problem almost overnight, effectively allowing people from all over the world in any location to become Safecast volunteers, regardless of whether or not they had met other Safecasters in person.

Fixed sensor transform kit

While the vast majority of our data comes from mobile devices, we have had a strong interest in having a fixed sensor network as well, especially from volunteers who own a bGeigie Nano. Many would like to be able to convert it into a static sensor so it can collect data at home or the office when they aren't using it to collect mobile data. We're currently developing an additional board that can be plugged into the XBEE header on existing bGeigie Nanos that will allow them to collect continuous data for a static location and automatically upload the readings.

For these purposes we're developing both hardwired (ethernet) and wireless (wifi and Bluetooth) options.

Local Government Measurement Program

In 2012 we started a program to work with municipalities in Fukushima to measure entire cities, street by street, to discover hotspots and establish values for the entire town. Though many radiation surveys were and are being done in the evacuation zone by the central government (see section 2.3 on Environment and Decontamination below), surveys have been inconsistently done in many other parts of Fukushima. Through this program we have measured four cities in Fukushima and are planning to remeasure these cities this year.

bGeigie Sharing Program

To get better milage from the fleet of bGeigies, we are working on a sharing program for bGeigie owners to make their bGeigies available to other volunteers in their communities.

1.3 Stationary Radiation Measurement

Safecast is deploying a new network of fixed realtime sensors.

In March, 2015, realtime.safecast.org launched. This new initiative is focused on deploying stationary radiation sensors in Japan and globally. These sensors will be sending real-time updates about radiation levels and publishing this data without interceptions as CC0 data.

The sensors in Japan will focus on areas around the Fukushima Daiichi plant, including the exclusion ("difficult to return") zone. We're working with volunteers who are in contact with evacuees who have expressed the desire to be able to check the radiation levels at their evacuated houses in realtime. For people living outside of the zone, we will work with volunteers to house the sensors. This will be strictly a "pull" model, where we're dependent on volunteers who are willing to support the initiative.

Initially we will deploy dual sensors that house two Geiger-muller tubes -- one that measures the dose rate equivalent (in µSv/h) and one “pancake” tube to measure the combined alpha, beta, and gamma activity in counts per minute (CPM). The sensor unit is manufactured by Medcom International and has been in production for the past 25 years. Sensors will installed outdoors, while the electronics (called an “nGeigie,” which stands for “network geiger counter”) will be be located indoors.

Currently over 20 realtime sensors have been deployed, and our goal is to deploy 25 more inside Fukushima over the coming months. This deployment is financially made possible by the Shuttleworth foundation.

nGeigie Fixed Sensors

nGeigie is the hardware platform for realtime.safecast.org. The system currently consists of a radiation sensor (Medcom Radius or Hawk) that is connected to a communications box (nGeigie) that relays radiation data realtime to the Safecast API. The initial deployment will focus on getting dense coverage across Fukushima, with some sensors also located in Tokyo and prefectures north of Tokyo. Work is under way to develop a simplified version that can be used in urban areas and will be inexpensive to build and easy to deploy.

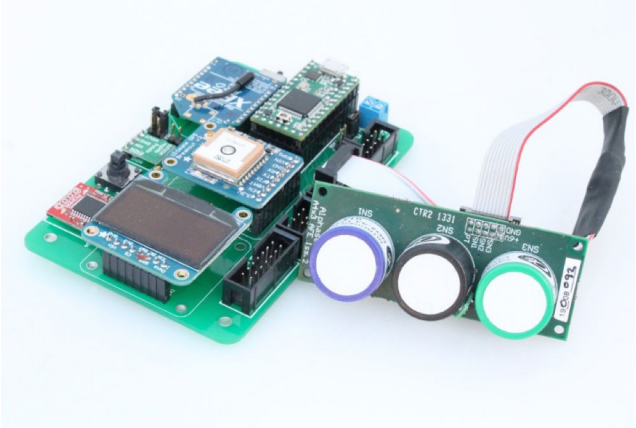
Safecast 6D

One limitation of using Geiger tubes is that they tell us how much radiation is present, but nothing much about the isotopes emitting the radiation. This is specifically important when measuring food, but this knowledge can also help us understand the main contributors to the levels measured in the environment and to help correctly compute the derived dose rate. In 2014 Safecast volunteers started to work on an new design and sensor selection to augment the bGeigie and nGeigie, which will be able to “see” more dimensions than in the data we currently collect. At present the project is in the concept stage.

ScanningTheEarth

In collaboration with Keio university, Safecast helped deploy approximately 300 radiation sensors across Japan as part of the Scanning the Earth project. The data was broadcast in realtime to a dedicated server hosted at Keio University. Softbank/Yahoo, which sponsored the project, shared the data for each location on Yahoo Japan on a dedicated webpage (“Radiation Forecast”). This page was regrettably discontinued in 2014, although the network itself remains up and running. One of the limitations of this network is that the sensors are located non-uniformly inside Softbank stores, often in a back room or a closet, and not outdoors, where they would have been more relevant from Safecast’s point of view. The realtime.safecast.org project is building on the experience from this project, and is focused on outdoor sensors and broader community to support the sensors.

1.4 Air Pollution Measurement



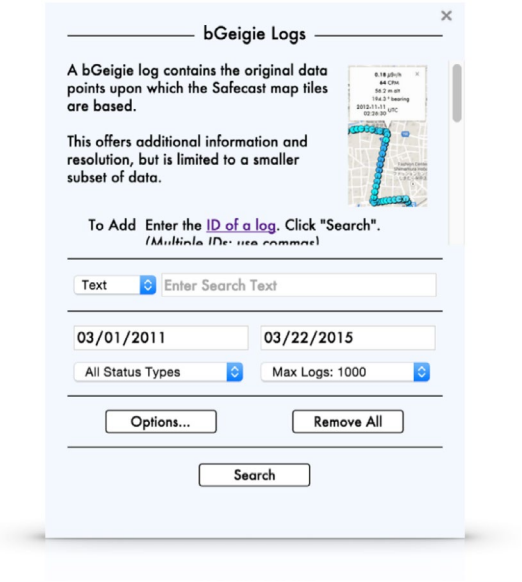
Safecast’s prototype air quality sensor.

While the primary focus of Safecast has been radiation measurements, we’ve always intended for the project to grow to include other environmental data. At first glance, air quality has many similarities to the concerns that attracted us to radiation. It’s generally invisible, and except in the worst cases one usually can’t just look outside and see it. Most importantly, no clear, reliable source of data accessible by everyone is available, and the data that can be found is often opaque and vague. With radiation we are measuring just one thing, but air quality in a much broader concept, and means many things to different people. Something that is a pollution concern in one city might not be in another, and this has led to much discussion and the constant question of what aspects of air quality are most important to measure, and for what purposes.

Also, unlike for radiation where there is a clear consensus about which sensors generate reliable data, air monitors are much more diverse and tend to be much less reliable. We’ve spent a significant amount of time and money trying to find and calibratable sensors that produce consistent measurements. At SCC2015 we are showing off a modular Safecast Air Quality prototype produced in conjunction with Pasadena based IO Rodeo. This device is based on the bGeigie form factor, and eventually could be fused with other sensors.

Additionally, we’ve been collaborating with the EDF, NRDC, MIT Media Lab, and Google on air sensors. Particulate pollution, specifically PM2.5, is of global interest and methane, a core greenhouse gas, is an important gas to quantify when considering climate issues. Future Safecast Air devices will likely monitor both of these.

1.5 Open Data (aka The Safecast API)



SAFECAST tries to set an example of openness in how we gather and present our data, and to demonstrate what the wider benefits of easy access to open data are for society as a whole. It's not just a matter of principle, but also one of pragmatism and practicality: we're convinced that the more open data is, the more useful it becomes.

Making everything openly available makes it easy for technically knowledgeable people to investigate our data and test its trustworthiness, and encourages many people to participate. We designed our system and our openness policies with demanding people and skeptics in mind. We wish this were the case for everyone publishing independent radiation data (or any data, for that matter), but it's not. There's no reason for the public to consider "independent" data more trustworthy than "official" data unless the people publishing it can demonstrate that it's technically comparable and also more transparent and free of possible bias. We encourage others to start with the assumption that their data cannot be considered trustworthy unless it can be easily and anonymously accessed by others and put to demanding analytical tests.

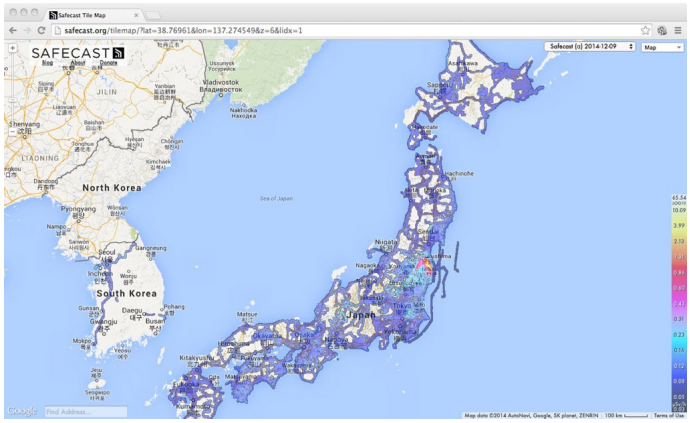
"Openness" is not something that can be easily added later, but needs to be integrated into the data collection system from the start, including insuring that there's a consensus among all the participants that it's a major priority. An open system doesn't have to cost more than one that's not, but it does require careful consideration and planning.

We recently posted a detailed FAQ about our openness and data access features:

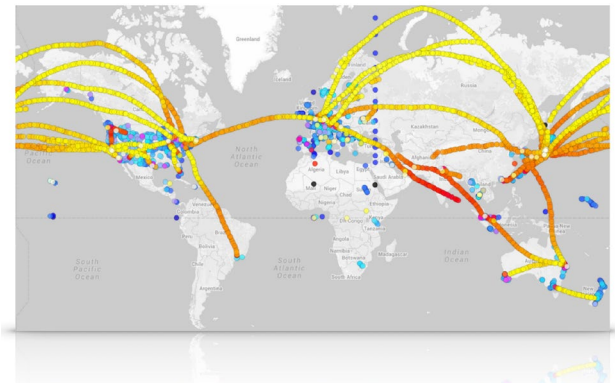
http://blog.safecast.org/faq/openness-and-data-access/

1.6 Data Visualization

1.6.1 Maps



Safecast's webmap has undergone several important revisions in the past year.



While not usually displayed on the Safecast maps, our dataset contains quite a lot of measurements taken during airline flights.

Over the last year the online Safecast map has seen a tremendous amount of evolution and improvement. Initially developed to create a basic visualization of aggregated drive data collected by mobile radiation sensors, the Safecast map now features:

- Multi layers allowing different data sets to be superimposed
- Ability to contrast individual drives with the overall radiation map. This is a great tool for volunteers to see their own drives in contract what others have measured
- Ability to compare current and past data sets
- See individual data points at any location
- Sophisticated interpolation algorithms to better show levels at any zoom level (far exceeding basic mapping tools offered by Google and the like)
- Display of realtime sensors

- High performance rendering
- Street view
- Various external data sets to compare with the Safecast data set

1.6.2 Apps

iOS and OSX

For iOS devices, version 1.7.1 of the Safecast app was released in 2014. This version notably included best-in-class gamma spectroscopy DSP (for scintillation counters) courtesy of Marek Dolleiser, from the renown PRA application for Windows. Ratemeter smoothing, significant energy consumption improvements, and an oscilloscope were also added. App settings also received extensive inline documentation for assisting users with Geiger and scintillation counter calibration.

The Safecast app for OS X was also introduced, based upon the tile engine used by the mapping features of the iOS app. In addition to providing a full desktop experience with the same dynamic and offline-capable functionality, the key feature of the Safecast OS X was exporting any layer or layers to web map PNG tiles quickly and efficiently, which paved the way for the new Safecast webmap. High performance was maintained by translating the ARM NEON SIMD intrinsics backend of the tile engine to Intel SSE. PNG tile creation was also heavily optimized and multi-threaded, resulting in fast tile creation and small filesizes that did not need to be pngcrushed.

Current development work is focused on unifying the codebases of the iOS and OS X apps, and porting tile engine code from Objective C to ANSI C for multiplatform capabilities and an open-source release. While in most cases this entails a complete code rewrite, there are benefits being realized in doing so, such as update tiling times of less than 10 seconds, an order of magnitude performance improvement to real-time IDW interpolation, and more. Open-source spinoffs from these efforts have been released on Github already -- Retile and bitstore.js.

The Safecast app for OS X allowed for the creation of web map tiles, and this created the opportunity to have an up-to-date webmap once again. Thanks to hosting efforts by Joi Ito and the MIT Media Lab, automated daily updates are now provided. With an interpolation layer developed by Lionel Bergeret, a realtime sensor layer by Kalin Kozhuharov, and a newly added bGeigie log viewer, the Safecast webmap has grown in both content and capabilities, with more on the way.

iOS maps

This year saw aggressive performance optimizations and the introduction of real-time IDW interpolation to the iOS app. Leveraging the fact the app stores data values rather than RGB colors, this allows for always-up-to-date interpolations of the Safecast dataset. The “see changes” layer operation was also significantly improved, providing literal highlights around new or updated data points since the last update.

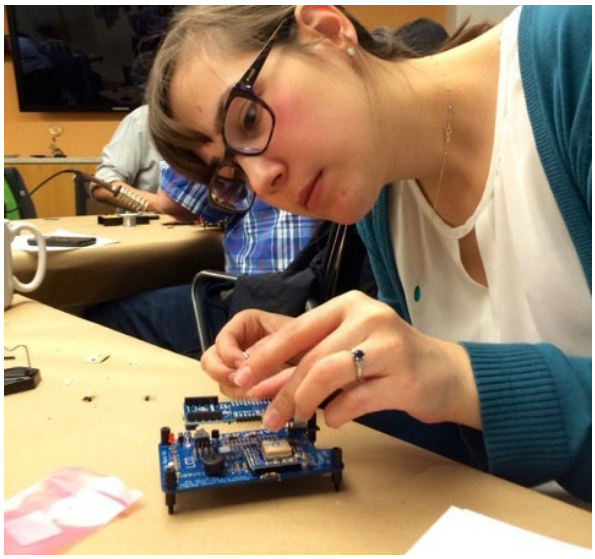
Some additional features have already been developed for the next release.

The basemap tile layer has been rewritten, and features best-match tile finding capabilities for much more practical offline use. Further, the performance of basemap network I/O and image processing have been significantly improved.

The data layers received some updates to the resampling code that both improves spatial accuracy and the masking used when the layer is resampled. Currently, all NODATA-masking is performed using nearest neighbor, and thus looks blocky. By using a thresholded Lanczos bitmask, the result is smoother contours that remain true to the original data points. A preliminary version of this is currently being used to render the non-interpolated Safecast webmap tiles for zoom levels 14 - 17.

1.7 Activities

From the start, we’ve considered events and activities to be an important part of communicating what we are doing, building our community, and training our volunteers. We frequently hold workshops, hold hackathons, give talks, and participate in public symposia. A few highlights from the past year have been:



Safecast workshop in Washington DC, sponsored by the NRDC.

bGeigie Workshops

We held quite a few bGeigie Nano building workshops in the past year, in Tokyo and Koriyama (Fukushima) in Japan, as well as in Washington DC, Cambridge, Taipei, and Strasbourg. Plans for workshops to be held this year are currently being made for Santa Monica, San Diego, and Berlin.

Hackathons

We held several hackathons in the past year as well, mainly in Tokyo, primarily to work on API and web issues.

Events and Talks

Safecast gets frequent requests to speak at public and private events, for groups of various sizes. In the past year

these have included a Gartner keynote and presentation to corporate leaders at CSLP, talks to students at International Christian University and Temple University Japan, in addition to a fundraiser, all in Tokyo. We also held an auction fundraiser in Los Angeles, and a closed presentation at Lincoln Labs at MIT. Many others are planned for 2015, including the Hills Summer Kids' Workshop program, for 5000 children, produced by the Mori Building Company in Tokyo.

Symposia etc,

We were happy to be invited to speak at important symposia in Japan and overseas, including an IAEA expert meeting and a disarmament and non-proliferation conference at the VCDNP, both in Vienna, and a public symposium in Tokyo jointly organized by United Nations University and UNSCEAR.

1.8 Outreach

We consider outreach and collaboration with universities and other academic institutions to be valuable community and skill builders. Ongoing and new collaborations include ones with MIT Media Lab, Keio University, Aoyama University, Kanazawa Institute of Technology, and San Diego State University.

1.9 Press & Publicity

The Safecast project emerged from the possibilities of the internet age and "runs" on a fabric of social media, the cloud, chat rooms, Slack, etc. Safecast does not spend any resources on advertisement, relying instead on word of mouth. However we do get coverage from various types of media regularly, and we see these as endorsement that what we do remains relevant. Over the past years we have been featured, mentioned, or covered in over 150 media publications - printed press, books, TV, blogs, online, etc.

Contributing to media is a significant activity for Safecast, as it allows our message to be propagated to a larger audience and also helps us to connect to new volunteers. Not only do we appear in articles, we also have become a go-to source for journalists who want to learn about radiation and scientific findings relate to the Fukushima disaster, and we have spent countless hours with reporters to share what we know and connect them with relevant people and organizations. We often accompany reporters into the field. We rarely seek coverage, however, and generally wait to be approached. When we feel information could be more accurately and informatively represented, though, we're not shy about reaching out to journalists with more reliable information as well.

Though we have historically gotten more media coverage outside of Japan than inside, over the past year Safecast has been well-covered by mainstream media in Japan. There are too many to mention, but we would like to highlight a few recent media appearances.

Recent Highlights:

- Mar 2015 - WDR (German public TV)
- Feb 2015 - NHK (E) - Joi Ito's TED talk was aired on Japan's national TV (NHK Super Presentation)
- Feb 2015 - NHK World aired a 30 minute special about Safecast made by documentarian Michael Goldberg as part of their "Inside Lens" series: http://www3.nhk.or.jp/nhkworld/english/tv/special/201502.html
- Feb 2015 - Asahi Shimbun (one of the top four newspapers in Japan) published a 20-article series about Safecast as part of the Prometheus Trap column.
- 2014 - South China Morning Post - Hong Kong's largest newspaper, wrote about the relatively higher radiation levels in HK versus Tokyo as measured by Safecast.
- Mar 2014 - NHK World News presented a 5-minute feature about Safecast's activity in Fukushima

Good Design Award

In 2013 Safecast received the Good Design Award for the Safecast Project as a whole. The Good Design Award is Japan's most prestigious award for what is deemed the leading edge in industrial design.

1.10 Funding & Support

NPO Status & Advisory Board

Safecast is a registered, US based non profit organization. Over the last year we have begun to set up an advisory board.

In addition to the US organization, there are plans to register Safecast as an NPO in Japan and Europe over the coming year to increase scope and outreach.

Shuttleworth Foundation

Sean Bonner was awarded a Shuttleworth Foundation Fellowship for the year 2014-2015 which, in addition to being a wonderful braintrust and support group, has provided funds to allow us to do the following:

- Stationary Sensors Project (nGeigie) - 25 sensors to be deployed in Fukushima over the coming 3 months

- Visualization - continuation of development of the Safecast maps and apps
- We now have new Makerbot Replicators and an Other Machine Other Mills in both Tokyo and Los Angeles, allowing us to speed up prototyping and share designs globally. We can have an idea in Tokyo, design a circuit board and case for it, and then simultaneously make exact copies in Tokyo and Los Angeles for testing purposes. This ability trims days and weeks from our design runway.
- The Safecast Conference 2015 was also made possible by Shuttleworth, and enabled us to bring many collaborators to Tokyo from overseas.

The Knight Foundation

Between 2011 and 2013, the John S. and James L. Knight Foundation was the primary funder for Safecast, awarding us several grants to aid with many different aspects of the Safecast mission.

Contributions in kind

We would like to thank the following companies for offering us help with our office, discounted equipment and services:

- Loftwork
- Medcom International
- Slack
- Adafruit
- Sparkfun
- Pelican Case
- Kromek (Safecast 6D)

1.11 Always Improving

Safecast is the work of volunteers, and is by no means "finished", "perfect" or "the final word". Some would say it's nothing to boast about -- lots of work to do! There's plenty of room for improvement and "wouldn't-it-be-nice-ifs." This applies to the Safecast Report as well. The information provided here represents the best data we have found, and the best of our understanding and knowledge, but, as a Dutch proverb goes, "Don't skate over one-night ice." We encourage readers and volunteers to check the data and information themselves and form their own opinions about the environment we're living in. "Is it safe?" is a question whose answer differs from individual to individual. Our daily lives are full of risks, but we shouldn't let that paralyze us.

However, being aware will hopefully allow us to make better decisions, and to focus our individual actions to better improve our environment and our lives.

If you see anything you think could be done better, needs fixing, or can be complemented, or if you simply want to help out or to contribute, let us know.

And if you want to learn how to make your data open and more useable (as a citizen, company, university, or government body), we're here to help.

Get in touch: info@safecast.org and @safecast on twitter

(and if we don't get back to you quickly enough, please read the previous sections to understand why!)

Safecasters Joe Moross & Kiki Tanaka

Safecast is people.

Part 2: SITUATION REPORT

Information compiled and summarized by Azby Brown, with contributions as noted.

Many thanks to Andrew Pothecary, designer of many of the infographics which appear on throughout the Situation Report section. Many of these previously appeared in the Number 1 Shimbun*, the magazine of the Foreign Correspondents' Club of Japan (FCCJ) and are credited as such, while others were made specifically for this report. We would also like to thank the many researchers and specialists who have given us valuable feedback on our drafts. Of course any errors are our own.*

A note before we start:

Compared to 2011, the Fukushima crisis is evolving more slowly that it had been. Nevertheless, it is difficult to keep up with changing circumstances and new information. While the core of SAFECAST's work is making crowd-sourced environmental monitoring data freely available online, we've also gathered a large store of data on issues such as the condition of the Fukushima Daiichi plant itself, the situation for evacuees, environmental consequences of the accident, food risks, and health issues. From the start we have made a point of talking to researchers regardless of their ideological stance on nuclear power, and over the past several years have fielded countless questions and requests for data, which we've always tried to respond to positively. The robustness of this dialogue has also made it possible for us to seek expert advice and opinion on many related subjects, and to pass this knowledge on to our community as well.

From time to time we have published in-depth blog posts on specific subjects, and made technical backgrounders available online, and have often pointed researchers, journalists, and others towards these to help them get up to speed. Quite a lot of technical information and many scientific reports are discussed, sometimes heatedly, on the Safecast Radiation Discussion Google Group < https://groups.google.com/forum/#!forum/safecast-japan >. The following Situation Report is an attempt to compile and summarize the most relevant, current, and accurate information we are aware of on the major aspects of the Fukushima disaster and make it available as a reference for anyone who is interested or has a need to know. Not surprisingly, we have been forced to leave out as much as we've included, but have taken pains to make it readable, and provide links to more in-depth documents wherever possible.

Every aspect of this disaster is accompanied by controversy, and we carefully guard against our own biases and strive to be as open and inclusive as possible. Some people will undoubtedly find that our information in some places contradicts what they've been led to believe. Others will feel we do not give sufficient weight to one opinion or another. We have concentrated on finding the best-documented sources, and have attempted to evaluate the evidence dispassionately. We welcome criticism, and urge anyone who would like to point out contradictory data not to hesitate to do so, because that is a challenge we particularly welcome. As mentioned above, we intend to update the Safecast Report on a regular basis, and would be pleased with any feedback which will help us improve it.

About information sources

The reliability of information has always been a major issue affecting our understanding of the Fukushima Disaster, and in fact the lack of reliable information during the early stages of the disaster was the reason SAFECAST was founded. In the following sections we describe the current situation at the Daiichi site itself, for the environment in general, for food, and for people's health, and cite our sources of information in each case.

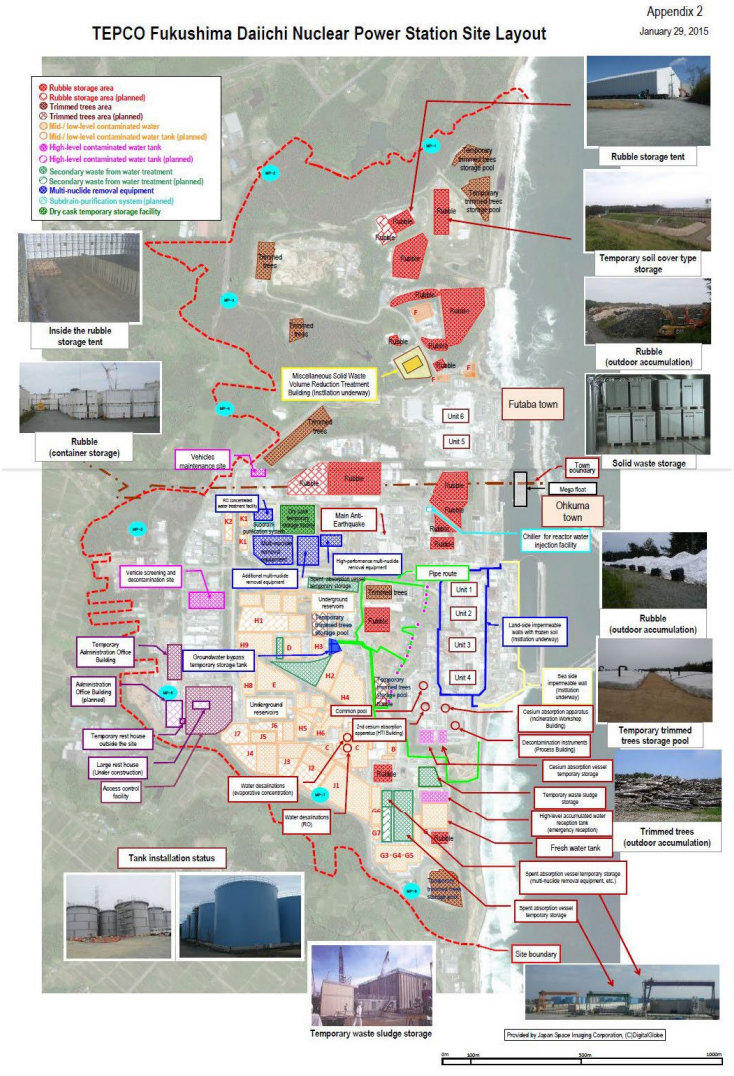
Official statements concerning ambient radiation levels in the environment, and to a lesser degree soil contamination, can be crosschecked against citizen science and academic research in most cases. Radiation levels and impacts in the ocean, with the exception of the immediate vicinity of Daiichi, have been very well documented by researchers, in a way which provides a useful cross-check against official claims concerning releases of contaminated water to the ocean, etc.. Food testing data from many independent groups is available as well as from the government. There has been little or no third-party verification of the decontamination process itself, but radiation levels can be easily confirmed for most locations if desired. Verifying the health monitoring done by the national and Fukushima Prefecture governments presents a higher technical hurdle, but several well-done health screening programs run by local governments as well as by community groups and foundations allow many useful comparisons to be made.

But for understanding what's happening onsite at the Daiichi plant itself, we are forced to depend on data provided by TEPCO almost exclusively, much of it presented with an obvious PR spin. Because there is almost no independent verification of measurements and work onsite, this data has an inherent unverifiability which in some cases can be significant. SAFECAST has consistently pushed for third-party verification of radiation monitoring at the Daiichi site and elsewhere, and while some TEPCO staff and gov't agency employees have privately agreed that it would be beneficial for everyone, including TEPCO itself, to adopt this kind of policy, none of our proposals have been accepted so far. Other qualified groups and researchers we know have made similar proposals and have also been rebuffed. But we won't give up, and will continue to press for the inclusion of third-party monitoring as a matter of course.

In the following sections, we begin with a general summary of each topic, followed by more in-depth discussion.

2.1- Issues at Fukushima Daiichi Nuclear Powerplant (FDNPP)

There are many continuing issues of concern at the Fukushima Daiichi site itself, and how quickly and well they are resolved will greatly influence the ultimate severity of the effects to the environment and to people's health. We quickly summarize the current status of decommissioning, removal of spent fuel rods, water problems, and other issues.



Recent site guide to the Fukushima Daiichi Nuclear Power Plant (FDNPP).(Credit: TEPCO)

Organizational acronyms:

JAEA: Japan Atomic Energy Agency

IAEA: International Atomic Energy Agency

NIRS: National Institute of Radiological Sciences

NRA: (Japan) Nuclear Regulatory Authority

METI: Ministry of Economy, Trade, and Industry

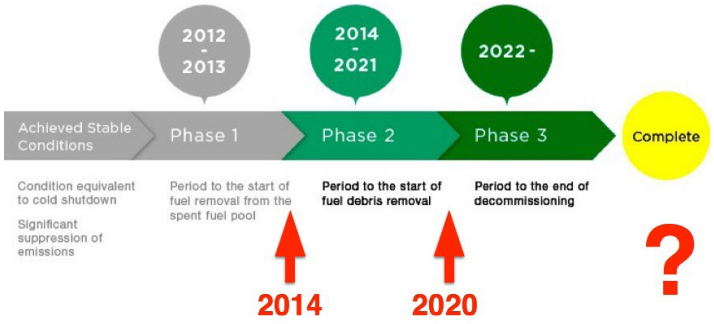
MEXT: Ministry of Education, Culture, Sports, Science and Technology

IRID: International Research Institute for Nuclear Decommissioning Recent site guide to the Fukushima Daiichi

2.1.1—Decommissioning roadmap

Briefly put, everything that is being done now and which will be done on site until the year 2020 is merely preparation for the really hard work of removing the melted fuel. There is a roadmap, and TEPCO is basically on schedule so far, but it gets much harder from this point forward. There is regulatory oversight, but we don't think it's intrusive enough.

TEPCO released it's first decommissioning roadmap — a timeline describing the expected schedule of work on the cleanup of the Daiichi site— in Dec, 2011, and has issued periodic updates, most recently through METI on Jan 29, 2015. It's a complicated document that points to the ultimate removal of melted fuel from the reactor containments at some as yet unknown date in the future, demolition of the buildings themselves, and remediation of the site. Much of the actual planning for later stages of the work cannot be done until success has been assured on earlier stages, particularly in solving the many water-related problems on the site. In fact, some of the technologies expected to be required for actually extracting the melted fuel do not exist yet. http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/conference-e.html



Long-term decommissioning diagram (Credit: TEPCO, annotations by SAFECAST)

This NRA document from Feb 2015 fills in a few details: http://www.nsr.go.jp/data/000098679.pdf

The overall long-term timetable has changed little since 2011, and is divided into three phases:

—Phase 1 (2012-2013): This involved stabilization and other work done prior to the start of removing spent fuel.

—Phase 2 (2014-2021): This is the current phase, and includes the continuing removal of spent fuel, and preparation for removing melted fuel debris from the reactor containments, including solving many water-related issues onsite.

—Phase 3 (2022 -?): This is the melted fuel removal and decommissioning process itself.

Many kinds of work are carried on concurrently, and TEPCO can be said to have met its primary goal for the end of Phase 1 and the start of Phase 2. In reality, the more detailed timelines are frequently adjusted, as are actual work targets, and often slip by months or longer. The 2014-2021 phase is very long, and this reflects the fact that many technologies do not exist for what needs to be done, and will require years of development. The melted fuel removal and decommissioning phase expected to start in 2022 currently has no estimated end point, though TEPCO has previously stated it would be 30-40 years from now. Based on prior experience at Three Mile Island and Chernobyl (where melted fuel has not yet started to be removed), we should assume it will require several decades.

TEPCO does not make its plans in isolation, but receives guidance and instructions from Japanese government agencies such as the METI, NRA, JAEA, NIRS, and IRID, and is required demonstrate to the IAEA that progress is being made onsite. NRA and IAEA conduct periodic reviews and onsite inspections, but we feel they lack the manpower, if not the mandate, to conduct the kind of unannounced daily inspections that seem to be warranted. The government seems to only know what TEPCO tells it, and the IAEA seems to depend primarily on information provided by the Japanese government. We're left to conclude that the only entity which really knows what's happening onsite is TEPCO itself, and that it is able to be selective about what data it releases, how, and when. The IAEA's most recent (preliminary) inspection report was issued on Feb 17, 2015. Documents released by UN agencies invariably adhere to a thick diplomatic language which requires a fair amount of parsing and reading between the lines. Not surprisingly, however, the IAEA reserved its strongest criticism for TEPCO's failures of management and oversight. Partly because of continued problems in these areas, we suspect, new corporate entities, the Fukushima Daiichi Decontamination and Decommissioning Engineering Company and the Nuclear Damage Compensation and Decommissioning Facilitation Corporation, have recently been established, intended to improve oversight of these critical long-term projects.

IAEA INTERNATIONAL PEER REVIEW MISSION ON MID-AND-LONG-TERM ROADMAP TOWARDS THE DECOMMISSIONING OF TEPCO'S FUKUSHIMA DAIICHI NUCLEAR POWER STATION UNITS 1-4 (Third Mission)
PRELIMINARY SUMMARY REPORT TO THE GOVERNMENT OF JAPAN
9 – 17 February 2015
https://www.iaea.org/sites/default/files/missionreport170215.pdf

Summary of decommissioning and contaminated water management, Jan 29, 2015
http://www.tepco.co.jp/en/nu/fukushima-np/roadmap/images/d150129_01-e.pdf

2.1.2— Spent fuel pools

Despite loud portents of doom in the global media,TEPCO succeeded in safely removing all of the spent fuel from Unit 4. This unit had the most fuel to remove, but the remaining three units will almost certainly be harder. The last are due to start being emptied in 2017. This fuel needs more secure long-term storage than in the common pool onsite, though there's really noplace else to put it yet.

One of the most critical ongoing tasks is the removal of hazardous spent fuel assemblies from the spent fuel pools of Units 1, 2, 3, and 4 (Unused fuel assemblies also need to be removed, but are not as hazardous). The process poses unique engineering and worker protection challenges, and serious mishaps could have wider negative consequences for the public and the environment.

Unit 4:

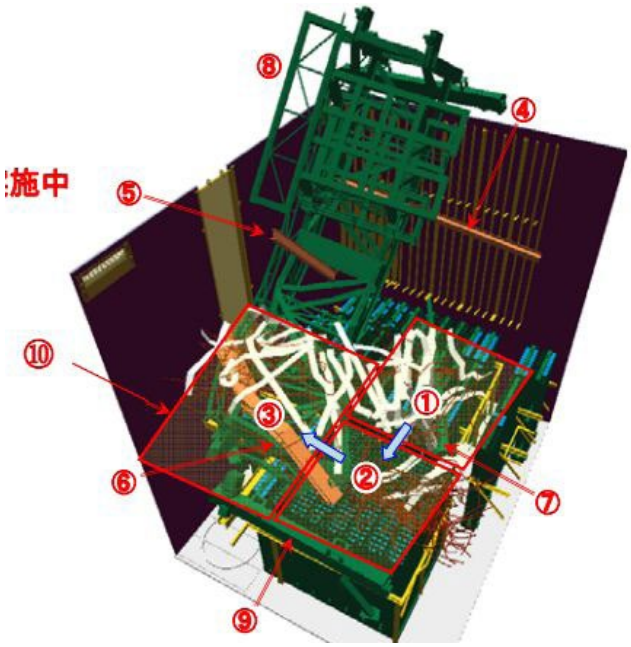
The removal of 1533 fuel rods from Unit 4's spent fuel pool was successfully completed without mishap on Dec. 22, 2014. The process necessitated removing a large quantity of rubble and dismantling unneeded upper structure, building a very large, multistory structure which cantilevered over the damaged reactor building, to stabilize it while not imposing any additional load, and installing new fuel handling machinery. The removed fuel assemblies were placed in fuel transfer casks, 71 times in all, and trucked a short distance to the common pool onsite at Daiichi, where it is expected to be stored for 10-20 years, and then transferred to more secure storage (though the decisions about how and where remain to be made). Prior to the commencement of this operation and throughout there were very loud and alarming claims from many quarters that failure was likely and that mishaps would lead to the extinction of the human race. Because we had looked closely at the seismic stability and structural damage reports for Unit 4 beforehand, we considered these claims to be extremely exaggerated, and in fact, giving credit where it is due, we have been impressed by the engineering design of this particularly challenging and unprecedented project. It can now function as proof of concept for the removal of spent fuel from the remaining reactor units.

Tepco info page about decommissioning, including PR videos:
http://www.tepco.co.jp/en/decommision/planaction/removal-e.html

Unit 3:

According to the current roadmap, spent fuel will next be removed from Unit 3, commencing in fiscal 2015. Although the 566 assemblies that need to be removed (514 used, 52 unused) are far fewer than there were in Unit 4, Unit 3 is almost entirely inaccessible to workers because of high dose rates. Work onsite is being done remotely for this reason, and the removal of the fuel rods is expected to be done primarily remotely as well. Removal of rubble from the roof was completed in Oct. 2013. The spent fuel pool is also full of structural debris which has been carefully mapped and modeled in 3D to help guide the remotely controlled removal equipment. There have been mishaps,

such as equipment accidentally dropped back into the pool while it was being removed, and highly radioactive dust being released while a large girder was being removed from the roof adjacent to the pool. Like Unit 4, Unit 3 will require a large structure which houses the necessary equipment to be erected in a way that places no extra load on the damaged reactor building.



3D debris map of Unit 3 spent fuel pool. (credit: TEPCO)

TEPCO, 3d debris maps etc, Jan 2015. (in Japanese)
http://www.meti.go.jp/earthquake/nuclear/pdf/150129/150129_01_3_5_07.pdf

Unit 2:

This spent fuel pool contains 615 fuel assemblies. Because this reactor did not suffer a devastating explosion like the others, the erection of a large separate structure will probably not be necessary. Nevertheless high dose rates will complicate the work, and the detailed plan has not yet been decided upon, though removal is currently being considered for commencement after fiscal 2017.

Unit 1:

This spent fuel pool contains 392 fuel assemblies, and the building is currently covered by a fairly lightweight structure intended to contain ongoing releases of radiation to the air, which will be dismantled in order to allow rubble to be removed. The final removal process has not yet been decided, but is being considered for commencement in fiscal 2017.

2.1.3—Water problems

We hear a lot about the water problems at the Daiichi site because they're serious and are an obstacle to starting the other work which needs to be done, and could directly affect the environment and marine life. If we could see the water that's causing the most trouble things would be a lot easier, but we can't because it's underground. The difficulty of the water problems has forced TEPCO to think ambitiously and innovatively, and appears to be advancing technology in some areas. But most of the other leaks which make the news (because they can be easily detected) have very low-tech, easily preventable causes.

Most readers are undoubtedly aware that tremendous water problems exit onsite at Daiichi. The root case is that both water which has been being circulated through the damaged reactors to cool the melted fuel as well as groundwater which has been leaking through the site and into the buildings themselves become contaminated, though precisely what it is coming into contact with remains unclear. Several measures, which TEPCO calls "contaminated water countermeasures," have been put in place to deal with various facets of the overall problem with varying degrees of success. Their approach can be divided into three main components, each of which involves several technologies:

1) To effectively filter the cooling water which is being recirculated.

2) To prevent groundwater from coming into contact with radioactive materials.

3) To prevent contaminated water from leaking out into the environment.

TEPCO claims to be making progress in all these areas, which the IAEA reservedly cited in its recent report, but without independent confirmation of radiation levels in the water onsite it is impossible to be certain.

2.1.3.a—Radionuclide removal systems

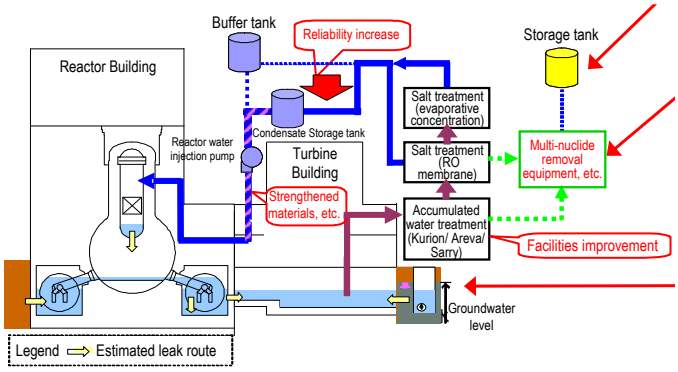
The systems TEPCO uses for removing radionuclides from water onsite started as an unreliable hack, but have gradually grown and become more stable. It's an incremental learning process that we're very familiar with. TEPCO has spliced together several different systems to make it possible to scale up and add new capabilities, and initiate new technological developments. The overall system seems to be performing well now, but there are still several weak points where breakdowns could lead to even more delays in processing all the water that needs to be treated.

TEPCO currently uses several water treatment systems — ALPS, SARRY, and Kurion — to remove radionuclides from the recirculating water. ALPS (Advanced Liquid Processing System), designed to remove 62 nuclides, is the largest system, and after a number of initial problems, in recent months it has reportedly been able to remove cesium to levels below detection with adequate consistency. Initially, the SARRY (Simplified Active water Retrieval and RecoverY system) and Kurion systems (Kurion is the name of the manufacturer) also only removed cesium. None of the initial systems were designed to remove strontium, however, which is one reason much of the treated water has had to be stored and could not be released into the ocean. A new Kurion Mobile Processing System which can remove strontium began operating in Oct. 2014, and a second unit in Jan. 2015. The SARRY system was also upgraded to enable strontium removal. Tritium remains a problem.

Though a few promising techniques have been demonstrated, tritium removal at this scale presently remains technologically unproven.

The IAEA feels confident that though it still contains tritium, if controlled releases of the treated water to the ocean were done there would be minimal impact to the environment, but this suggestion has unsurprisingly met with opposition from local fishermen. According to the IAEA, over 1 million cubic meters (m^3) cumulative volume of water has been treated, and about 600,000 m^3 of contaminated water is currently stored onsite, about half of which has been treated and the targeted nuclides also reduced to non-detectable levels. Construction of new tanks has barely outpaced the production of contaminated water, and periodic leaks from the tanks have highlighted deficiencies in management and oversight. TEPCO initially expected that the backlog of water to be treated would be completed by the end of fiscal 2014, but has recently pushed this target back by several months. It is unknown if and when an agreement to allow the release of water containing tritium will be reached. The alternative is to continue to build storage tanks onsite, until, perhaps, a viable large-scale tritium removal system is developed.

Kurion to Sign Contract Over Fukushima Cleanup, WSJ Sept. 17, 2014
http://www.wsj.com/articles/kurion-to-sign-contract-over-fukushima-cleanup-1410940529

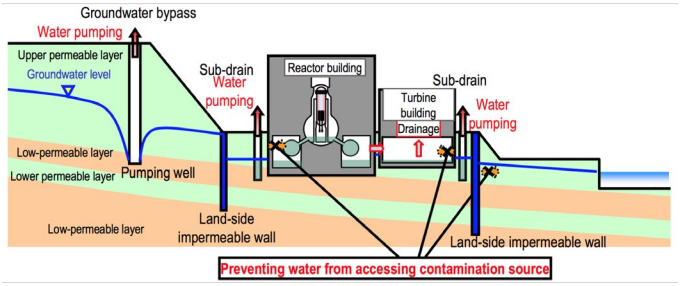


Schematic diagram of the overall water treatment system. (Credit: TEPCO)

2.1.3.b— Groundwater problems

Briefly put, the planned solution is an ambitious series of underground dams made of ice (frozen soil, to be exact), and dozens of pumps. The pump part would be easy if the water wasn't radioactive. All the eggs are in this basket, and we haven't heard of a plan "B" in case it fails. Unless the groundwater problem is solved, it won't be possible to carry out the next steps to prepare for removing the melted fuel.

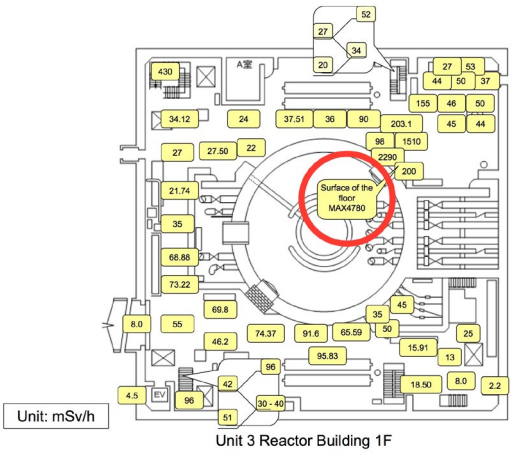
According to the IAEA and other sources, approximately 300 m^3 of groundwater enters the reactor buildings per day, a problem which is rooted in the initial siting of the building. Though the ground level where the building sits was originally much higher, major excavation was done to lower the site in order to make the pumping of water from the ocean easier, bringing the buildings into contact with the permeable geological layers through which groundwater flows. Under normal conditions the buildings had an adequate seal against this water, as well as efficient "subdrain" pumps to remove it, but since the 2011 disaster large amounts of water have been entering the reactors, apparently through cracks or other openings underground. Exactly how and where remains a mystery. Several methods of dealing with this water are being tried.



Schematic sectional view of the Daiichi site showing planned relationship of groundwater levels, underground ice wall ("land-side impermeable wall"), pumps, etc. (Credit: TEPCO)

— Sealing the buildings

Sealing any below ground-level openings in the reactor buildings would seem to be the best and most direct option for keeping groundwater out, and efforts are being made to identify where the leaks are and develop sealing methods. But the radiation levels inside and next to the reactor buildings are generally too high to allow humans to work for any length of time. In fact, radiation in many parts of the buildings is high enough to give lethal exposures within a short time (over 5000 mSv/hr in Unit 1, 4400 mSv/hr or over in Units 2 and 3). Techniques for repairing cracks and other gaps remotely are being investigated, and are expected to be required in order to prepare the structures for the removal of melted fuel after 2022, but they do not currently exist. In the meantime the groundwater causes so many other problems that it must be dealt with soon.



TEPCO plan showing locations of high doserates in the reactor buildings. (Credit: TEPCO)

—Groundwater Bypass

Because the groundwater is flowing into the site from the mountains on the side opposite the ocean, it has been hoped that intercepting as much of this water as possible before it reaches the site could greatly reduce the amount reaching the reactor buildings. Groundwater on the uphill mountain side so far has not shown high levels of radioactive contamination, so after an agreement was reached

with local fishermen to have it stored and independently tested before being released— the only agreement of this sort reached so far — the pumping and diversion of the water was begun in April 2014. The IAEA says that this has reduced groundwater ingress by approximately 25%, not as much as was hoped, but an improvement nonetheless.

—Subdrains

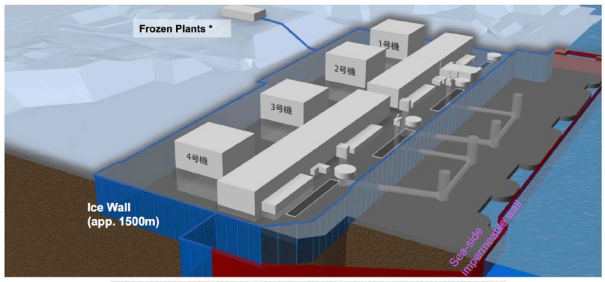
A system of about 40 drain pumps, called "subdrains," located near the reactor and turbine buildings, existed prior to the accident. These were intended to mitigate potential problems from groundwater during normal operation of the plant, but were seriously damaged and have been unusable since March 2011. Repairs to this system are reportedly nearly complete. Once back in operation, the subdrain system should initially be able reduce the amount of water entering the buildings by 150 m^3 per day, according to the IAEA (TEPCO's own estimate is 500-700 tons, roughly 500-700 m^3). Once the frozen earth wall is successfully in operation, these drains should theoretically be able to reduce water inflow to zero. This water will be purified and stored in tanks, like the water from the groundwater bypass, and subject to similar third-party monitoring conditions and the approval of local fishermen before any is released. But due to increased opposition from the local fishermen's union in the wake of recent revelations that other contaminated water has been secretly released from the plant, such an agreement may be difficult to reach.

Groundwater pump-up by Subdrain or Groundwater drain

http://www.tepco.co.jp/en/decommision/planaction/subdrain/index-e.html

—Frozen underground wall

After examining several alternatives, TEPCO decided upon a controversial plan to construct a 30 meter-deep wall, or dam, of frozen earth around the reactor buildings in hopes that this will provide an effective barrier to water ingress. The planned structure, called the "land-side impermeable wall," will form a rectangle approximately 500m by 200m, with a total perimeter of about 1500m. Though the frozen earth technique is well-proven and is often used in very challenging mining and tunneling operations, the wall at Daiichi is the longest ever actually attempted, and is being done with an ever-present radiation hazard as well as many underground obstacles. Onsite tests began in August 2013, construction began in June 2014, and the freezing operation is now due to start in April, 2015. If all goes according to plan, the wall will greatly reduce the water inflow, but much about the plan remains unpredictable. If the water pressure outside the buildings is less than it is inside, for instance, they are likely to continue leaking, possibly more than before. TEPCO seems to hope that any leakage will be contained within the perimeter of the frozen wall, and intends to pump water in and out to maintain the proper pressure levels. Again, while we believe that the overall plan is technically sounder than many critics have claimed, we think the challenges should not be underestimated and we retain some skepticism. Even if it is only partially successful at lowering the groundwater level onsite, however, it should make other aspects of the work easier in the future.



TEPCO schematic showing the placement of the underground ice walls. (Credit: TEPCO)

— Sea-side impermeable wall

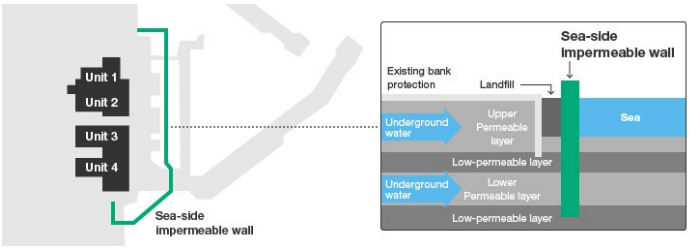
Groundwater samples taken from observation wells in the area between the reactor buildings and the ocean front (intake and port areas) have regularly shown high levels of radionuclides, particularly gross beta (which includes strontium) but also cesium. In Oct. 2014 samples from one set of wells showed over 7.8 million Bq/L gross beta, which declined to 500,000 Bq/L by Jan. 2015. Although the total radiation levels are many thousands of times lower than they were in March and April, 2011, this kind of contaminated water has continued to seep into the ocean, primarily contaminating and recontaminating the seabed offshore. While the continuing releases are notable and need to be stopped, as far as we can tell, even after several years at the current rates they will probably add less than 1% to what the initial releases dumped. To stop this seepage, TEPCO has constructed a 30m deep wall of sheet pilings called the "sea-side impermeable wall" along the ocean frontage of the site, about 780m in total length, and as of Jan. 2015 this was 98% complete. An approximately 10m wide opening still remains, and though we have not yet found clear information from TEPCO about it, we conjecture that it will be left until the results of the frozen wall become clear. In the meantime it allows a limited flow of contaminated groundwater into the partially-enclosed port area. TEPCO regularly releases test data for water taken from the port area as well as from offshore (see section 2.3.3 - The Ocean), but we feel that not all relevant locations are covered, and reiterate that without independent confirmation some skepticism remains about the accuracy of the figures TEPCO provides.

Analysis Results of Groundwater Obtained around Fukushima Daiichi NPS, March 20, 2015

http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/tb-east_map-e.pdf

Analysis Results of Seawater Obtained around Fukushima Daiichi NPS

http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/2tb-east_map-e.pdf



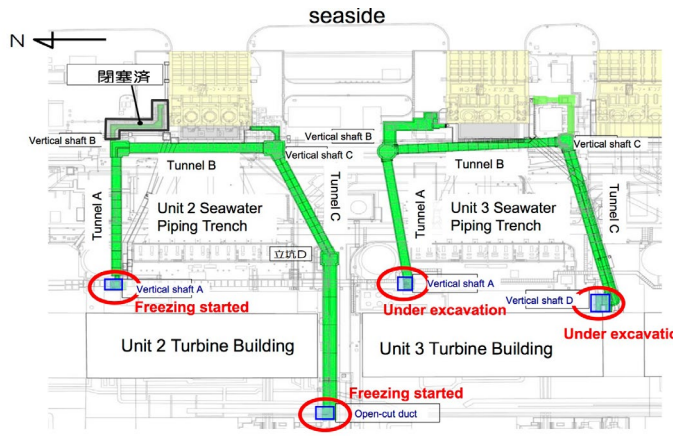
Schematic plan and section showing the placement of the seaside impermeable wall, underground layers, and the ocean.(Credit: TEPCO)

—Trenches

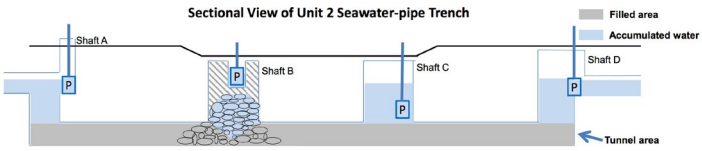
Each of the reactor turbine buildings is connected to seawater intake pumps and other equipment at the waterfront by interconnected underground tunnels called trenches, for seawater piping and power cables primarily, as well as a number of connecting shafts and smaller underground structures. The trenches of Units 2 and 3 in particular became filled with several thousand tons of highly contaminated water during the early phase of the disaster, and due to continuing leaks and poorly-understood flow mechanisms, now appear to contain a mixture of contaminated cooling water and groundwater. This water must be removed before the freezing of the earth wall can be done nearby. TEPCO considered several methods, and began by attempting to make frozen plugs at one end of the seawater piping trenches of Unit 2, which they hoped would allow the water to be easily pumped out and treated afterward, and could be repeated at Unit 3's trenches. The method apparently worked in experiments but failed in practice. In Nov. 2014 TEPCO started pumping water out of the Unit 2 seawater piping trench, making it possible to pour a concrete special cement mix (grout), which was completed in mid-Dec. 2014. As of Feb. 2015, the same procedure was being used for the seawater piping trenches of Unit 3 and Unit 4.

Progress of blocking water at connection of trenches and the Units 2 / 3 reactor facilities, July 23 2014

http://www.jaif.or.jp/english/news/2015/current-status_fukushima-daiichi_150127.pdf



Plan of underground trenches at Units 2 and 3 (Credit: TEPCO) Credit:



TEPCO

Unfolded section of Unit 2 trench showing portion filled with concrete. (Credit: TEPCO)

2.1.4— Melted fuel removal

This has only really been done once before, at Three Mile Island, where melted core removal was completed in 1990, (it has not yet been attempted at Chernobyl), so there are not many people with experience to call on for assistance. The job is too big for any one company to tackle, so a new, well-funded research institute has been established to incubate the kinds of technologies that will be necessary. The process will require decades.

Removing melted fuel from inside the damaged reactors and storing it safely is the primary goal of the decommissioning process. As mentioned above, this will not actually start until around 2022. Fundamentally, everything that has been done onsite until now and which will be done until the actual removal process begins is preparation for that stage. Because of the tremendous technical challenges involved, which exceed the experience and know-how of any existing single company, the International Research Institute for Nuclear Decommissioning (IRID) was established in 2013. This consortium is under the guidance of the Japan Atomic Energy Agency and the National Institute of Advanced Industrial Science and Technology, and includes as founding members major corporations such as Toshiba, Hitachi-GE Nuclear Energy, Ltd., and Mitsubishi Heavy Industries, Ltd., as well as major electric utilities from around the nation. IRID's primary mission is to research and develop the necessary technologies for decommissioning the nuclear reactors, which it seeks to do in cooperation with companies and organizations both inside and outside of Japan.

IRID has been very active, seeking and funding proposals and organizing meetings and workshops, some of which have had tangible results, but it is still far too early to make any firm decisions about how the actual melted fuel removal work will be done. The current front-running idea, however, is called the "submersion method." This involves plugging leaks in the reactor containment so it can be filled with water, and then using remote-controlled machinery inserted from above on long telescoping arms to cut up and extract the melted fuel in pieces. The following video explains the process under consideration:

IRID Explanatory video for Submersion Method for Fuel Debris Retrieval, May 2014

http://irid.or.jp/en/video/

Before this can be done, the melted fuel must be located, the reactor buildings decontaminated and shielded so that workers can enter, power and communications re-established inside the buildings, and methods developed to minimize the further spread of contamination during the decommissioning process. Meanwhile, though some initial progress has been made, most of the robotic equipment necessary to survey inside the torus rooms and lower levels of the containment buildings is still being developed. This is necessary both to identify places that need repair prior to submersion, and also to locate the melted fuel itself. The sobering reality is that the technology for dealing with most of the tasks that melted fuel removal will entail does not yet

exist.

Muons are subatomic particles that are created when cosmic rays pass through the Earth's upper atmosphere. The use of muon tomography for locating melted fuel has met with considerable success in tests, and equipment was installed outside Unit 1 on March 10, 2015. The detection system currently being installed measures the number and trajectory of muons after they have passed through objects. Because nuclear materials are denser than other metals and concrete, their location can be readily identified using this technology, much like an X-Ray. The team, led by the High Energy Accelerator Research Organization (KEK), reported their results on March 20, 2015, saying that nuclear fuel was not detected within the reactor containments, lending strength to the assumption that it all melted and dropped to the concrete floor below. Measurements at Unit 2 using a different type of muon detection system developed by Toshiba is expected to be begin onsite around October of this year, though a team from Nagoya Univ. was also reported to have done similar scan tests at Unit during 2014; at the time of this writing those findings have not yet been made available.

Reactor imaging technology for fuel debris detection by cosmic ray muon: Measurement status report in Unit-1 March 19, 2015
http://www.tepco.co.jp/en/nu/fukushima-np/handouts/2015/images/handouts_150319_01-e.pdf

Placement of muon detectors, Feb. 9, 2015 (in Japanese)
http://www.tepco.co.jp/nu/fukushima-np/handouts/2015/images/handouts_150209_08-j.pdf

COMMENCEMENT OF REACTOR INTERIOR SURVEY USING 'MUON PERMEATION METHOD' (FEBRUARY 12, 2015) http://irid.or.jp/en/topics/「ミュオン透過法」による炉内状況調査の開始に/

Tokyo Electric Power : Nagoya University confirms Fukushima No. 2 reactor meltdown
http://www.4-traders.com/TOKYO-ELECTRIC-POWER-CO-I-6491247/news/Tokyo-Electric-Power--Nagoya-University-confirms-Fukushima-No-2-reactor-meltdown-20060203/

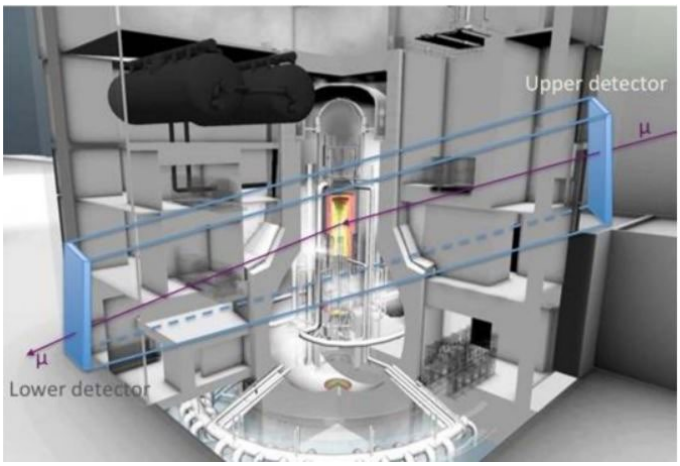
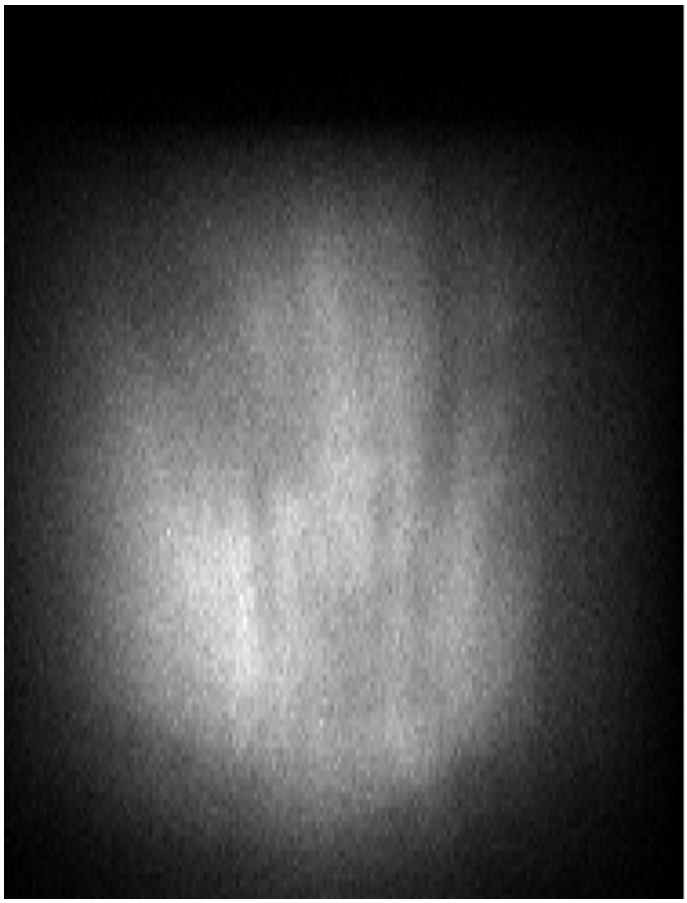


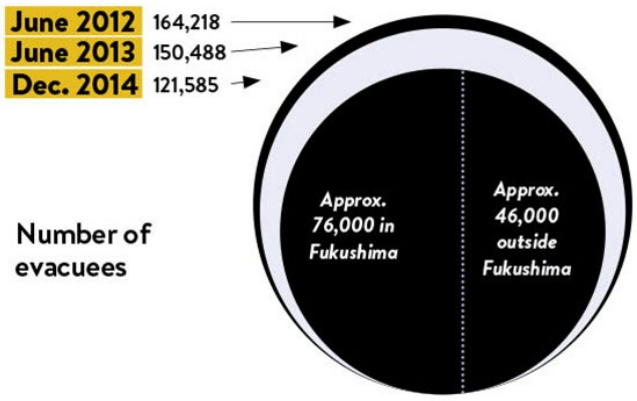
Diagram showing placement of muon scan detector plates to be used at Unit 2. (Credit: TEPCO/IRID)



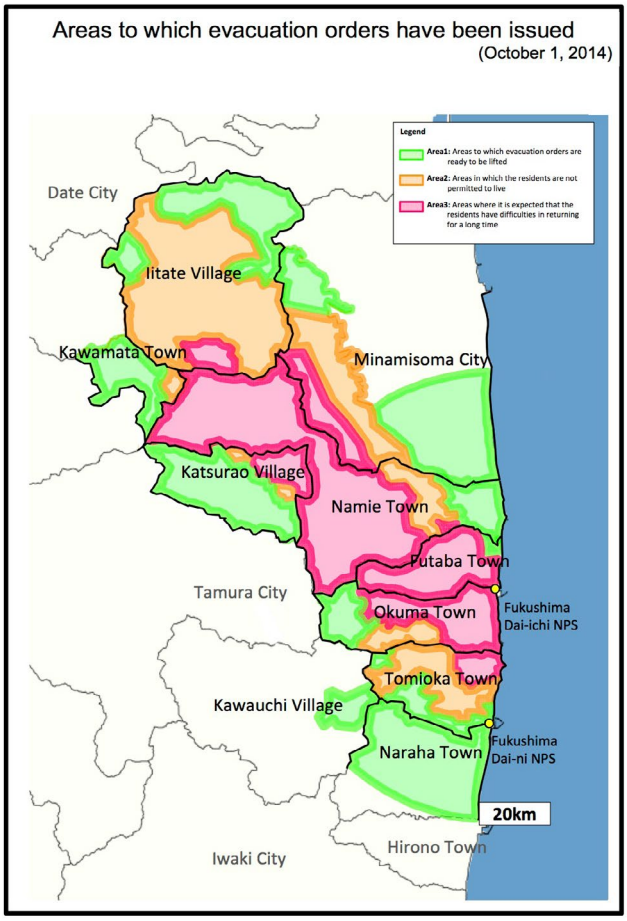
Muon scan image of the interior of Unit 1 pressure vessel, March 2015. (Credit: TEPCO)

2.2- EVACUEES AND RETURNEES

Their lives are uprooted, and their grievances are immense and deep-seated. Much of their plight is rooted in hastily made decisions about where to draw lines between the evacuated and those who were allowed to remain -- assuming they wanted to, or would be financially able to leave if they didn't. At the moment, not many evacuees want to return to their abandoned home towns despite enticements from all levels of government, but quite a few who lived outside the evacuation zones have returned. Meanwhile a huge disparity in compensation has driven communities even further apart.



(Credit: FCCJ; graphic by Andrew Pothecary)



The evacuation zones as of Oct 2014.(Credit: METI)

2.2.1—Number of evacuees

According to Fukushima Prefecture, as of late January 2015, the number of evacuees stood at 121,585, down from 164,218 in December, 2012, of whom about 85,000 had been ordered to evacuate by the government, while the remaining 75,000 or so were living outside the mandated evacuation zones, and evacuated "voluntarily." Of the present 121,585 evacuees, roughly 79,000 cannot return home until their towns have been declared open again; about 42,000 have no such legal barrier to return. Currently, about 76,000 live in other municipalities within Fukushima, and about 46,000 are outside Fukushima Prefecture.

Fukushima Prefecture gives the following breakdown:

— From the "Difficult to return" area (red on official maps): 24,400 people (9100 households).

— From the "Residence prohibited" area (orange on official maps): 23,000 people (8,400 households).

— From the "Prepare to return" area (green on official maps) : 31,800 people (10,900 households).

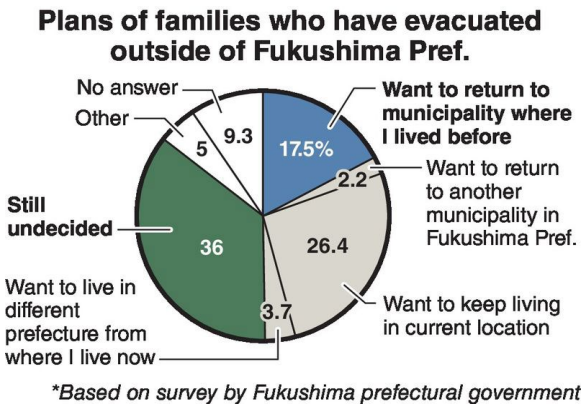
— From the former "Evacuation prepared" zone (between 20-30 km): 20,000 people (household breakdown not found).

— From other parts of Fukushima Pref.: 28,000 people (household breakdown not found).

Steps for Revitalization in Fukushima, Jan 30, 2015
https://www.pref.fukushima.lg.jp/uploaded/attachment/100867.pdf

At present, the rate of return to newly reopened communities such as the eastern part of Kawauchi-mura, reopened in Nov. 2014, and the eastern part of Miyakoji, reopened in April 2014, has been low; population remains 10.5% and 39.1% of pre-disaster totals, respectively, despite what some consider a concerted "safety campaign" on the part of the government.
http://mainichi.jp/feature/news/20150307mog-00m040006000c.html

In fiscal 2014, a government survey was done which covered households from seven municipalities affected by evacuation orders. 48% of the 16,600 respondents said they do not plan to return home, up from 30-35% in previous years. A similar Reconstruction Agency survey which was conducted between August and October, 2014, covering evacuee households in hard-hit Namie, Futaba, Okuma, and Tomioka, showed that only 10-20% overall desired to return. Continuing concern over radiation is given as a primary reason, but there are many other factors which make staying away the most compelling choice for many households. Families with young children are the



Evacuee survey results, 2014 (Credit: The Japan News)

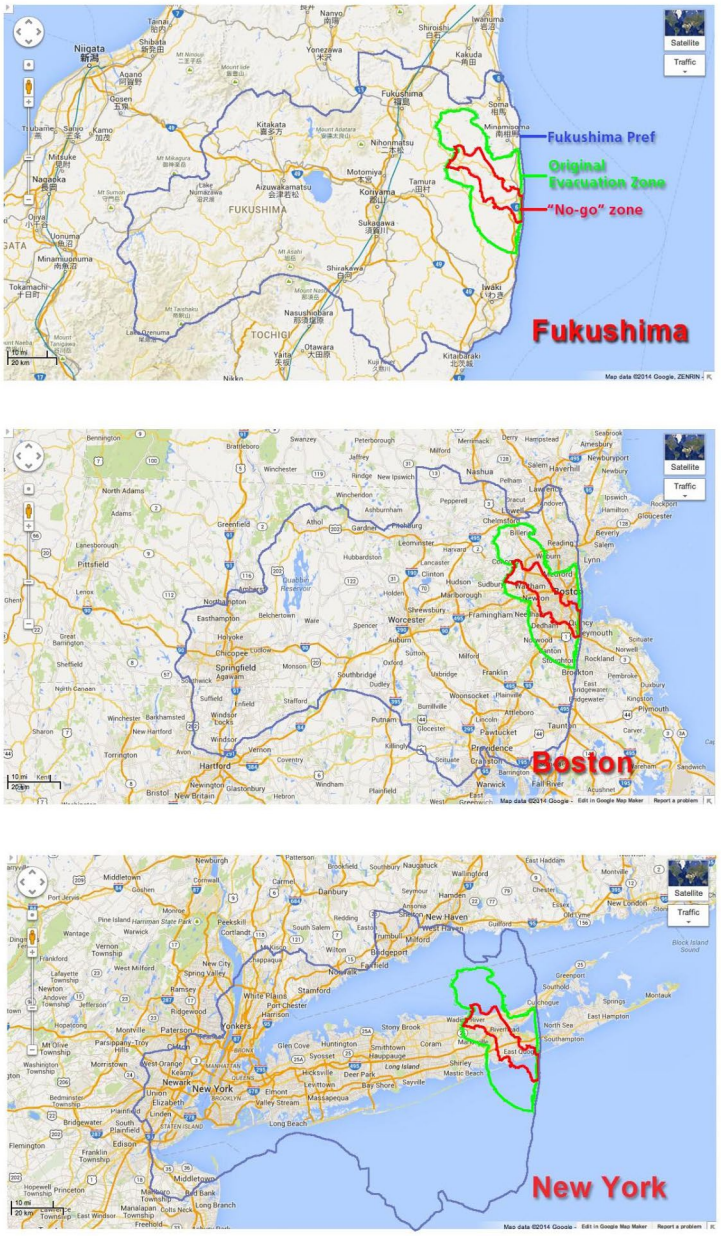
most likely to stay away, and few older people want to live in towns with nothing but old people. Infrastructure, transportation, and other services can be restored, but these communities have lost their vitality as well as their tax bases, and though subsidies can help, without young people and new businesses the future is likely to be one of merely marking time. The lack of young people was already a serious problem before the disaster. Many households depended upon agriculture or fisheries for their livelihoods, but despite rebounding markets in a few categories, the Fukushima stigma is likely to depress sales for years to come. In order to encourage voluntary evacuees to return, in 2012 Fukushima prefecture started offering rent-free housing in selected areas where radiation levels are low, and this may account for some of the returning population since then.

http://ajw.asahi.com/article/0311disaster/fukushima/AJ201502250050

http://www.japantimes.co.jp/news/2015/03/04/national/more-fukushima-evacuees-are-deciding-to-stay-away-for-good/#.VPqJjoGUc3S

http://www.japantimes.co.jp/news/2014/03/10/national/267000-still-evacuees-three-years-on/#.VPvWYUL3r8k

It should not be forgotten that the entire tsunami-affected Tohoku coast faces a similar problem, with a roughly equal number of evacuees, though in their case the actual rebuilding of infrastructure and places to live is still years away for most. Official evacuee data for Iwate and Miyagi, the two prefectures most hard hit by the tsunami, has a number of uncertainties. The biggest is that many people evacuated without notifying authorities, and have kept their original official addresses. The system put in place by the Ministry of Internal Affairs and Communications for tracking evacuees in Tohoku has come under strong criticism for its inadequacies, such as frequent failures to remove the names of people who have returned from the system. To some degree these problems affect evacuee records in Fukushima as well, but because a special law was enacted on their behalf in 2011 to enable them to obtain administrative services in their places of temporary residence, and because most of them qualify for compensation payments, most appear to have registered and updated their evacuee



Fukushima and the evacuation zones compared to Boston and New York. (Credit: SAFECAST)

status. For this reason, Fukushima Pref.'s evacuee records are more complete than those of Iwate and Miyagi. Nevertheless, researchers and others believe that serious gaps exist between the official records and the actual displacement of affected persons in the entire Tohoku region.

Keeping these uncertainties in mind, recent data from the Reconstruction Agency gives the following numbers, as of Feb 12, 2015:

Currently living in:

Iwate: 29,433
Miyagi: 70,949
Fukushima: 72,790 (as opposed to Fukushima Pref's most recent figure of about 76,000)

Total number of evacuees living outside these 3 prefectures: 128,481

(The Reconstruction Agency data does not make it easy to determine how many of these are from each affected prefecture).

http://www.reconstruction.go.jp/topics/main-cat2/sub-cat2-1/20150227_hinansha.pdf

http://www.kahoku.co.jp/tohoku-news/201406/20140622_71017.html

Problems with evacuation policy are dealt with in detail in the NAIIC report:

National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), 2012
https://www.nirs.org/fukushima/naiic_report.pdf

Also in independent reports such as this:
IDDRI - Disaster Evacuation from Japan's 2011 Tsunami Disaster and the Fukushima Nuclear Accident, 2013
http://www.devast-project.org/img/research/STUDY0513_RH_DEVAST_report.pdf

2.2.2— Compensation

Regardless of whether they were ordered to leave or did so voluntarily, all evacuees from the nuclear accident qualify for or have received financial compensation from TEPCO, ultimately paid for by taxpayers, though the amounts differ greatly depending upon this status. From the start the compensation scheme was confusing and controversial, and has been revised several times. Regardless, the overall process of obtaining compensation from TEPCO has been very complicated and slow in general, and depends upon time-consuming arbitration. In areas where evacuation was mandated, within each community citizens are likely share similar grievances, and the biggest divide is between those who lived in areas which have a good chance of being reopened in the near future and those from the "difficult to return" zone, primarily the towns of Namie, Futaba, and Okuma, for whom return is many years away at best.

The compensation system is discussed in detail in this OECD report:

Japan's Compensation System for Nuclear Damage - As Related to the TEPCO Fukushima Daiichi Nuclear Accident, 2012
http://www.oecd-nea.org/law/fukushima/7089-fukushima-compensation-system-pp.pdf

TEPCO publishes compensation payment totals monthly, but the guidelines upon which the listed categories are based, as well as detailed breakdowns in terms of how much has been paid per person or per household, are difficult to find:

Records of Applications and Payouts for Indemnification of Nuclear Damage, Feb 27, 2015
http://www.tepco.co.jp/en/comp/images/jisseki-e.pdf

This states that to date 4,271.2 billion yen in compensation has been paid in total:

2,090.3 billion yen to forced evacuees

353.0 billion yen to voluntary evacuees

2,118.1 billion yen to businesses

When the amounts in each category are simply divided by the number of evacuees, however, the results are implausibly high:

Forced evacuees: 85,000 = ¥24,591,764 per person

Voluntary evacuees: 75,000 = ¥4,706,666 per person

This news article from October, 2013, gives average compensation payments given to households at that time (note that the dollar equivalents given here are based on ¥100 = $1.00 for simplicity, though the actual rate fluctuates).

Panel willing to extend compensation period for Fukushima evacuees
http://ajw.asahi.com/article/0311disaster/fukushima/AJ201310260046

It states that, according to the Evaluation Committee For Nuclear Damage Compensation Disputes, as of Sept. 20, 2013, an average family of four forced out of no-entry zones had received about 90 million yen — about $900,000 — in compensation from Tokyo Electric Power Co..

The average payments which make up this total include:

49.1 million yen ($491,000) for property, such as real estate, building and furniture

10.9 million yen ($100,900) for lost wages

30 million yen ($300,000) for psychological suffering

An article from Dec. 2013 gave similar figures:

TEPCO to pay evacuees additional 7 million yen for 'loss of hometowns'
http://ajw.asahi.com/article/0311disaster/fukushima/AJ201312270055

25,000 people from "difficult-to-return zones" qualify for:

7 million yen ($66,700) for "loss of hometown"

14.5 million ($145,000) yen per person, total compen sation

For a family of 4:

From "difficult to return" zone :
106.75 million yen overall ($1,067,500)

From "residence restricted" zone:
71.97 million yen overall ($719,700)

From "prepare to return" zone:
56.81 million yen overall ($568,100)

Based on compensation standards set by the evaluation committee and TEPCO, the government had previously estimated that four-member families would receive 63.03 million yen ($630,030).

Finally, a recent Asahi Shimbun article gives a breakdown of payments received for due per person for psychological suffering:

http://www.asahi.com/articles/DA3S11628201.html

For mandated evacuees:

From “difficult to return” zone :
14.5 million yen ($145,000)

From “residence restricted” zone:
7.2 million yen ($72,000)

From “prepare to return” zone:
4.8 million yen ($48,000)

For voluntary evacuees:

From within the 30km zone:

High-school age and under:
2.15 million yen ($21,500)

Adults:
1.8 million yen ($18,000)

From Fukushima City, Iwaki, and 21 other towns:

Children and pregnant women:
520,000 yen ($5,200)

Others:
120,000 yen ($1,200)

From 9 towns in southern Fukushima, also Marumori-mura in southern Miyagi:

Children and pregnant women:
280,000 yen ($2,800)

Others:
40,000 yen ($400)

Again, these amounts are for psychological suffering only, and do not include other compensation for property, lost wages, etc..

Recent payment breakdown data is hard to find, and it is difficult if not impossible to verify the amounts that have been paid. Various payments, such as compensation for lost wages and to businesses, initially were scheduled to stop after a few years, but in many cases affected people have successfully lobbied for the payments to be extended. Evacuees also have been receiving 100,000 yen ($1,030) per month in psychological suffering compensation. This money is paid unconditionally, but is stipulated to stop one year after the resident returns to their reopened hometown. Government programs to subsidize housing for returnees seems to be intended to compensate for this, but the payments act as a disincentive to return. Evacuees are eligible for most of their other compensation payments whether they return or not, and the government reportedly would prefer to offer lump-sum payments instead of periodic ones, in order to remove the fear of losing payments as a deciding factor in return.

Some recent media accounts have reinforced the impression that the apparently high compensation evacuees have received have made them the object of resentment in other communities in Fukushima. Many communities have been split between the well-compensated and the poorly compensated, and in towns such as Iwaki, which have received a large number of evacuees, many local residents apparently feel that evacuees are parasites living on the dole.

Fukushima fallout: Resentment grows in nearby Japanese city, Reuters, Aug 21, 2014

http://www.reuters.com/article/2014/08/31/uk-japan-nuclear-resentment-idUSKBN0GV0XN20140831

The reality is that for a family forced to leave a homestead and community in which they have lived for generations, and to be deprived of their accustomed livelihood, it is difficult to say that any compensation can ever be adequate. Undoubtedly cases of abuse and unjustified payment exist, and these sometimes appear in the media. But the main problem, often pointed out by outside observers, is that no realistic guidelines for compensation were in place prior to the disaster, and many subsequent decisions concerning evacuation were made in ways which split communities along mandated and unmandated lines, though the affected families may have lived on opposite sides of the same street. Add to this the mistrust of government assurances concerning the safety of the decontaminated areas to which they are being asked to return, and the suspicion that promised payments will not in fact be received, and great disincentives to return exist and continue to divide affected communities.

2.2.3—Evacuee housing

The situation in Fukushima is complicated by the fact that the prefecture has evacuees affected by the both the earthquake and tsunami and by the nuclear disaster, and must provide housing for both. Housing falls into two categories, temporary housing units, generally prefabricated, and standard dwelling units, such as apartments, which are subsidized by the prefectural government. Although a clear breakdown has not been found, in terms of “nuclear” evacuees, Fukushima prefecture is primarily concerned with housing the portion of the 76,000 evacuees currently living in Fukushima that were forcibly evacuated.

The prefecture has built 16,607 units of temporary housing altogether, and rented an additional 18,686 units, for the use of both earthquake/tsunami and nuclear evacuees. Temporary housing was intended to be used for only 4 years, but has been extended through March 2016. In addition, new public housing is being constructed; while 1070

of the 2702 units intended for earthquake/tsunami evacuees have been completed, only 261 or the 4890 units for nuclear evacuees have. Considering that these can serve only a small portion of the total number of evacuees, it is clear that alternate arrangements are being used by most.

Steps for Revitalization in Fukushima

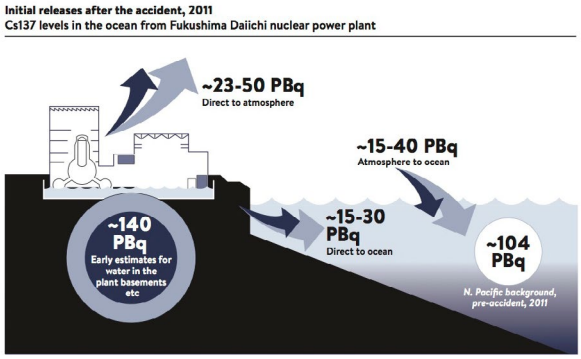
Fukushima Pref., Jan 20, 2015
https://www.pref.fukushima.lg.jp/uploaded/attachment/100867.pdf

The lack of fully equitable compensation and housing arrangements, which would clearly not present coercion to return nor incentive to relocate, and would not favor some community members over others, has been presented as a human rights issue. In fact, we have spoken with forced evacuees who feel they are well apprised of the risks, but would like to return immediately nonetheless, and feel that their rights are being infringed by not be allowed to. We have heard from more citizens, however, who resent the fact that despite well-documented contamination in their neighborhoods, they did not qualify for evacuation and full compensation.

2.3- ENVIRONMENT and DECONTAMINATION

The radioactive releases to the environment from Fukushima Daiichi are unprecedented in many respects, but also comparable in many ways to releases from other accidents and from nuclear weapons testing. Radionuclides are both persistent in the environment and mobile, and it's of paramount importance to locate and track them as they disperse through the ocean and migrate into the soil and through watersheds, to know where to expect food species to be contaminated and by how much, and where the places where people live will require remediation, or even abandonment.

2.3.1—Overview



(Credit: SAFECAST; graphic by Andrew Pothecary)

The levels of radiation in the post-accident environment do not remain constant, but change over time due to physical decay of nuclides, as well as their mobility within ecosystems due to migration into the soil and through watersheds, their dispersion through the oceans, uptake and dispersion by plants and animals, and other processes known collectively as "weathering." In this section we will deal briefly with the most relevant impacts of Fukushima radiation on the environment.

Presently the scientific consensus is very strong that approximately 80% of the fallout from Fukushima Daiichi was carried over the ocean, while the remaining 20% fell on land. Several reports of the overall releases, their likely timing, and their ultimate deposition on land and in the ocean have been issued by official agencies and other researchers. UNSCEAR analyzed and cited 16 Fukushima source term studies, and noted:

"For 131I the estimates ranged from about 100 to 500 PBq; for 137Cs they ranged, in general, from about 6 to 20 PBq."

UNSCEAR Report, 2013 (published 2014)
http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

(A very complete list of 16 studies is given in Table B2 of the UNSCEAR report). They acknowledged that the estimate produced by a JAEA team (Terada et al) was at the lower end of the estimates they considered, and may underestimate the total releases by a factor of about 2. But they felt it fit best with measured observations for deposition on land and so was the most useful for use in estimating doses to people. Another comparison and review of several estimates by organizations including JAEA was released in 2013 by the National Institute for Environmental Studies, and also concluded that release and deposition studies done by JAEA best fit the actually measured Cs-137 deposition pattern:
http://pubs.acs.org/doi/abs/10.1021/es304620x

The JAEA team studying the source term has published a revision to their findings, and raised their estimate of total I-131 releases from 120PBq to 142.9PBq, and Cs-137 releases from 9 PBq to 12 PBq. The revision might lead to some small increases in dose estimates for people in certain areas, keeping in mind that the revision supports prior estimates that about 27% of the release was deposited over land, and 73% of that was over forests, not populated areas.

JAEA source term study:

Detailed source term estimation of the atmospheric release for the Fukushima Daiichi Nuclear Power Station accident by coupling simulations of atmospheric dispersion model with improved deposition scheme and oceanic dispersion model

Katata et al, Atmos. Chem. Phys. Discuss., 14, 14725–14832, 2014
http://www.atmos-chem-phys-discuss.net/14/14725/2014/acpd-14-14725-2014-print.pdf

Final version published Jan 2015
http://www.atmos-chem-phys.net/15/1029/2015/acp-15-1029-2015.pdf

Finally, the Science Council of Japan also published a comparison of several estimates in Sept. 2014. Prof. Jay Cullen of the Univ. of Victoria, in British Columbia, who also runs the very informative Fukushima INFORM web site, summarized the findings as such:

"1. The study estimated the atmospheric release of 137-Cs of 19.4 +- 3.0 PBq through the end of March 2011 which is in between previous high and low estimates.

2. Best estimates of direct ocean discharge of 137-Cs to the Pacific in addition to atmospheric deposition are 2.3 to 26.9 PBq and the panel could not determine which model provided the most robust estimate.

3. About 19.5 +- 5% of releases were deposited to land while about 80% ended up in the Pacific Ocean.

4. The distribution of 137-Cs in the ocean can't be reproduced without atmospheric deposition and direct ocean releases to the Pacific."

Cullen also notes that the Fukushima 137-Cs releases are notable smaller than the ~100 PBq released by the Chernobyl disaster in 1986.

http://www.dailykos.com/story/2014/09/08/1328170/-How-Much-Radioactive-Material-Was-Released-by-Fukushima

Science Council of Japan comparison, part 1:
http://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-22-h140902-e1.pdf

FukushimaINFORM:
http://fukushimainform.ca

2.3.2—The land environment

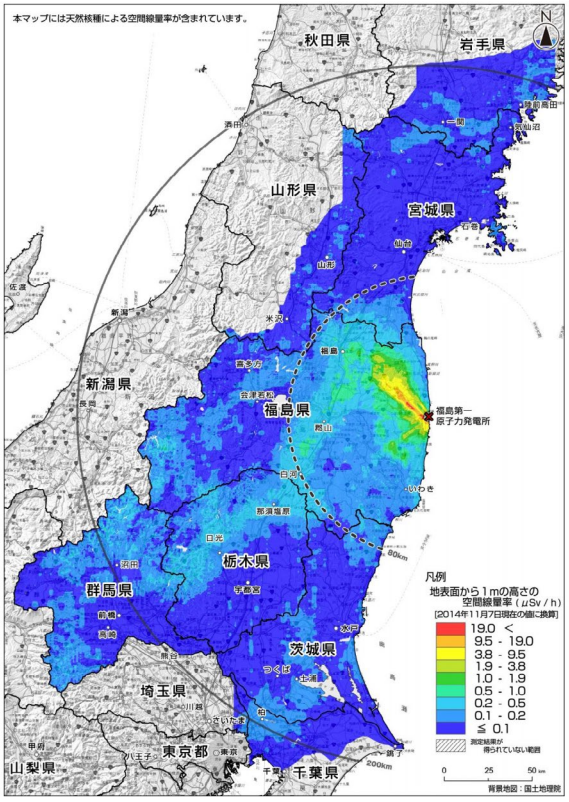
Odd though it may seem to say it, we were lucky that only about 20% of the radioactive releases from Daiichi ended up on land. Even that much has caused the displacement of over 100,000 people, and necessitated very costly remediation of farmland and living areas. Fortunately as well, most kinds of environmental radiation is not very difficult to detect and map. This is why SAFECAST exists.

The Japanese government released it's first radiation map of the 80 km radius area around the plant, based on aerial surveys, in early May 2011. Results of many gov't radiation surveys have been released since then, with gradually improving access and presentation. Nevertheless, we still feel that the maps and other data are rarely presented in a way that makes them intuitively usable by the general public.

http://radioactivity.nsr.go.jp/en/

http://ramap.jmc.or.jp/map/eng/

http://emdb.jaea.go.jp/emdb/en/

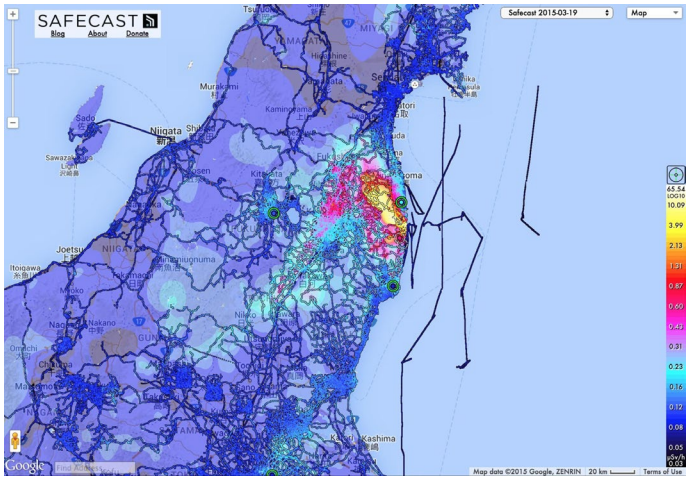


Japanese gov't map showing radiation levels as of Feb. 2015

The most recent fallout map released by the NRA is here:

http://radioactivity.nsr.go.jp/ja/contents/11000/10349/24/150213_9th_air.pdf

Safecast's radiation database includes some data readings taken from aboard ships, as well as some from aircraft (which are not included in our main maps), but over 99% are land-based readings. We are often asked how our data compares to official data, and we usually point out that during the first several of months of the disaster Safecast was often able to publish data for areas of Fukushima and the rest of Japan where little or no official data was available, and today we are still able to provide more detailed coverage than is available on most official maps. Nevertheless, the radiation levels recorded by our volunteers generally match official data within a reasonable margin of error. As our work has demonstrated, ambient radiation levels can effectively be verified by independent citizens' groups.



A screenshot of Safecast's web map from March 19, 2015.

Safecast's web map:
http://safecast.org/tilemap/

To adequately verify the levels of radionuclides in the soil, however, currently requires much more expensive equipment. Cesium and other gamma-emitting nuclides in soil can be adequately measured with equipment similar to that used for measuring food, though detecting strontium, for instance, is a several-day process within the capability of only very sophisticated labs. Many soil contamination maps have been released by Japanese gov't agencies, including several for Sr-90 and Pu-238, Pu-239, Pu-240, and some university-based researchers have done their own analyses. While few specialists believe that enough soil sampling has been done for these nuclides, it is generally accepted that the overall ratios of cesium to strontium have been adequately characterized. Nevertheless, because these ratios will change over time due to the differences in physical half-life as well as mobility in the environment, improved monitoring is important.

Official soil sampling maps:
http://emdb.jaea.go.jp/emdb/en/selects/b223/

The *Minna no Data* project has begun an independent crowdsourced soil survey. Not much data is available yet, but over time this should prove to be a valuable resource:
http://en.minnanods.net/soil/

2.3.2.a—Forests

About 70% of the fallout that fell over land ended up in forests, which will be impossible to effectively decontaminate, and where it will remain bioavailable to plants and wildlife for decades. Radionuclides have essentially hijacked the watershed, turning it into a cesium delivery system (while delivering smaller amounts of other nuclides as well). Fortunately researchers have a lot of experience tracking them in these environments.

It is estimated that the majority of the radioactive substances which fell over land in Japan fell on forested mountains. This is a mixed blessing. It is fortunate because population in Japan, including in Fukushima, is concentrated in valleys and on plains, and the mountains themselves are very sparsely populated. It is unfortunate because most observers have concluded that it will be impossible to adequately decontaminate the forests themselves, and so for many coming years — decades — dose rates in the forests will be higher than elsewhere, sometimes significantly, and people will need to exercise adequate caution when entering them.

Basically, trees and other biota continually recycle cesium and other nuclides within the ecosystem. Typically, for instance, radioactive substances are taken up by tree roots, and a portion ends up in the leaves. These fall and form a layer of ground litter on the forest floor, and as they decay the nuclides migrate into the soil again, where they can be taken again up by roots, thus perpetuating the cycle. Some species, such as mushrooms, easily take up cesium, for instance, and when these are eaten by forest animals some is deposited within their bodies, but all is eventually excreted, and can become bioavailable in the soil again. Nuclides can enter streams and ponds along with mineral and organic matter, and much of it will be transported through the watershed and eventually to the ocean, while a significant portion will end up in streambeds and lakebeds and stay there for years. Near inhabited areas, it has been effective to clear away the contaminated ground litter, and if this is repeated regularly long-term reductions can be made. It is because this is infeasible in most of the mountainous forested areas themselves that it will necessary to restrict access to them until natural radioactive decay and transport have resulted in sufficiently reduced radiation levels.

Environment Ministry info pamphlet about forest contamination (in Japanese)
http://josen-plaza.env.go.jp/materials_links/pdf/shinrin_20140221.pdf

Several good studies of the radioactive change processes in forests and watersheds affected by the Fukushima disaster have been released:

Forest studies:
Kato et al, 2014:
http://www.aesj.or.jp/publication/pnst004/data/018_022.pdf

Murakami et al, 2013:
http://www.nature.com/srep/2014/140108/srep03599/full/srep03599.html

Ohte et al, 2013:
http://www.rri.kyoto-u.ac.jp/anzen_kiban/outcome/Proceedings_for_Web/Topics_1-07.pdf

Hashimoto et al, 2012:
http://www.nature.com/srep/2012/120525/srep00416/full/srep00416.html

Watanabe et al, 2012:
http://www.rri.kyoto-u.ac.jp/anzen_kiban/outcome/Proceedings_for_Web/Topics_2-14.pdf

MEXT, 2012:
http://radioactivity.nsr.go.jp/en/contents/1000/294/24/PressR04%200802s.pdf

Watershed studies:
Evrard et al, 2013:
http://www.nature.com/srep/2013/131029/srep03079/full/srep03079.html

Yamashiki et al, 2014:
http://www.nature.com/srep/2014/140116/srep03714/full/srep03714.html

Lepage, Evrard, et al, 2014:
http://www.proc-iahs.net/367/237/2015/piahs-367-237-2015.pdf

Chartin, Evrard et al, 2013:
http://www.sciencedirect.com/science/article/pii/S2213305413000088

2.3.2.b—Decontamination progress, plans, effectiveness

The area needing to be decontaminated is huge. When we investigated the results of the techniques being used two years ago, we concluded that it was only partly effective, and that in many situations it made more sense to wait for natural radioactive decay to take its course. In some cases decontamination appears to be what we call an “optical” solution — to show that efforts are being made. But much of the time it can make a big difference in radioactive exposures and doses. Regardless, it’s a management and communication nightmare, and we’re not surprised many residents remain skeptical.

The policies and practices which drive decontamination are rooted in decisions made regarding the health and safety of affected residents, particularly evacuees. Decontamination has been controversial from the start, and has suffered from a lack of transparency in much of Fukushima. We published a long blog post in August, 2013 explaining the thinking behind the official policies and guidelines and evaluating the effectiveness of the techniques. Most of what we wrote then is still valid, and readers interested in knowing more about the policies and the overall background behind the present situation should refer to that post:

http://blog.safecast.org/2013/08/decon-or-con-how-is-remediation-being-managed-and-how-effective-is-it/

— Issues and problems

Among the most widely cites issues with the decontamination process are:

- Claims that the targeted radiation levels are not low enough to ensure adequate safety
- Inadequate oversight
- The generation and temporary outdoor storage of tons of contaminated debris.
- Lack of responsiveness to requests by citizens for more thorough decontamination to be done of "hot spots" in specific areas.

This situation is ripe for abuse, and back in January, 2013, the Asahi Shimbun published a scathing series of exposes detailing sloppy work practices and fraud, titled **"Crooked Cleanup":**
http://ajw.asahi.com/article/0311disaster/fukushima/AJ201301040058

In January, 2013, after these revelations were made, the Environment Ministry issued revised guidelines which presented "Lack of viewpoints of locals and third-parties" as one cause of problems, and suggested "Effective monitoring by a third-party etc." as part of the solution. Since then, we have asked Environment Ministry representatives on several occasions what the procedure was for becoming a third-party monitor. As recently as Feb. 2015, the reply has been that this has not yet been implemented. Usually, the representatives we've spoken with are chagrined to admit this, because many of them recognize the need and feel that it will help lead to better results overall as well as greater trust. We intend to keep asking.
http://josen.env.go.jp/en/documents/pdf/securing_appropriate_decontamination_works.pdf

—What's been completed so far?

As we explained in our "Decon or Con" blog post, decontamination of areas which were subject to evacuation orders, known as the "Special Decontamination Area," which includes 11 municipalities in all, is done under the jurisdiction of the central gov't, specifically the Environment Ministry. All other areas are grouped in to the "Intensive Contamination Survey Area," and decontamination there is the responsibility of the respective local governments, with financial and technical support from the central government. This area includes 100 municipalities in 8 prefectures where additional exposure doses exceeding 1mSv/y of were measured, 39 of them in Fukushima, and as far away as Gunma, Saitama, and Chiba.

A total of 13,000 sq. km. (a bit smaller than the state of Connecticut) both inside and outside of Fukushima was over an additional 1 mSv/yr in Nov 2011, and designated for either full decontamination or survey for "hot spot" decontamination:

http://www.asahi.com/special/10005/TKY201110110128.html

Information on overall progress can be found at the Environment Ministry's **"Decontamination Information Plaza" website:**

http://josen-plaza.env.go.jp

http://josen.env.go.jp/en/

We pointed out some of the problems with this site and the information in provides back in 2013. It has gradually become more easily usable, but while an effort is being made to have complete and up to date information available, it's necessary to examine data for each municipality separately, and so it's difficult to get an overall picture of the current state of progress. Very few dose-rate maps are provided, either.

For the "Prepare to return" (green) and "Residence prohibited" (orange) parts of the evacuated areas, decontamination was declared completed in the towns of Kawamata (houses only), Tamura, Kawauchi, Katsurao (houses only), Okuma, and Naraha in 2014. Kawamata and Katsurao are scheduled to be fully completed in fiscal 2015, and the portions of the other towns which lie in these zones, Iitate, Minamisoma, and Tomioka, are scheduled to be completed in 2016. No decontamination is scheduled yet for the "Difficult to return" (red) zone, nor for nearly unpopulated mountainous portions of Namie and Minamisoma which lie in the orange zone.

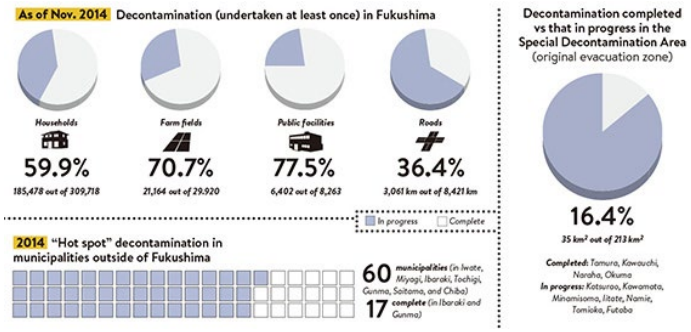
Schedules and progress:

http://josen.env.go.jp/material/pdf/josen_gareki_progress_201503.pdf>

In other words, the government expects to complete all decontamination in areas it intends to reopen for evacuees to return to by 2016. This does not mean that ambient dose rates will be reduced to 1 mSv/yr throughout these zones. It also does not mean that no further decontamination will be attempted. Rather, the current thinking is that as long as personal dosimetry results can demonstrate that the majority of the returnee population will incur doses not much above 1mSv/yr, it will be possible to use individual dosimetry results to counsel each person about how to further minimize their doses. Based on what we have seen, the central government does not intend to produce an approved "counseling manual" but has been encouraging local governments to develop their own programs based on local community experience.

As mentioned above, no decontamination is planned yet in the "red" zone, and no timetable has been officially proposed for the return of evacuees. Nevertheless, based on conversations we've had with knowledgeable people, we would not be surprised if the government ordered selective decontamination in some places in this zone a few years from now in the hopes that people who wanted to return could be allowed to do so by 2020. Such a decision, if in fact it is made, will surely be very controversial.

– How much land area has been "decontaminated" at least once?



(Credit: FCCJ; graphic by Andrew Pothecary)

—In Fukushima (as of March 2015)

In the "Special Decontamination Area" (original evacuation zone), 11 municipalities total:

Total are to be decontaminated: 248 sq km

Decontamination completed:

Tamura, Kawauchi, Naraha, Okuma

Total target area: 3500 ha. (35 sq km)

In progress:

Katsurao, Kawamata, Minamisoma, Iitate, Namie, Tomioka, Futaba

Total target area: 21,300 ha (213 sq km)

39 municipalities in Fukushima outside of the evacuation zone (in the "Intensive Contamination Survey Area"):

Work is in progress in most, and has been completed in 3.

—Outside of Fukushima

60 municipalities in Iwate, Miyagi, Ibaraki, Tochigi, Gunma, Saitama, and Chiba (in the "Intensive Contamination Survey Area"):

Work is in progress in most, and has been completed in 11 towns in Ibaraki and 6 in Gunma.

http://josen.env.go.jp/area/index.html

—Decontamination completion breakdown by category, in Fukushima (as of November 30, 2014):

Households:
185,478 (59.9% of 309,718 planned by end of 2014)

Farm fields :
21,164 (70.7% of 29,920 planned by end of 2014)

Public facilities:
6,402 (77.5% of 8,263 planned by end of 2014)

Roads:
3,061 km (36.4% of 8,421 km planned by end of 2014)

Most recent info sources:

Fukushima prefecture:

Steps for revitalization in Fukushima Jan 2015

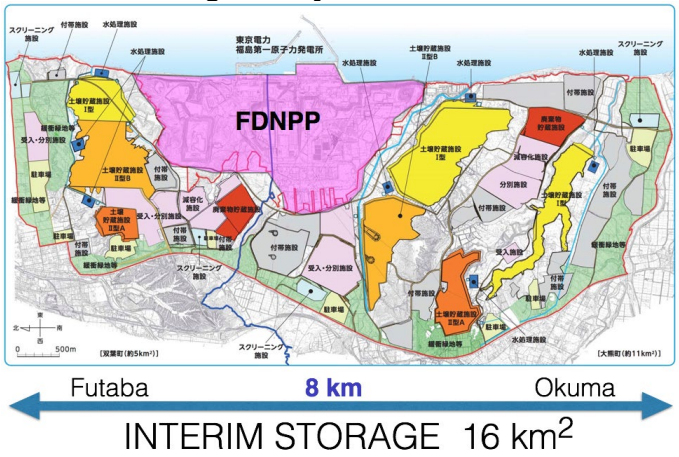
https://www.pref.fukushima.lg.jp/uploaded/attachment/100867.pdf

Environment Ministry:
http://josen.env.go.jp/area/index.html

Japan's Decontamination Efforts and its Effects, July 2014
http://josen.env.go.jp/en/documents/pdf/japan_decontamination_efforts_and_its_effects.pdf

Progress on Off-site Cleanup Efforts in Japan, Jan 2015
http://josen.env.go.jp/en/pdf/progressseet_progress_on_cleanup_efforts.pdf?141022

—Interim storage facility



Plan of interim storage area. Yellow and orange areas represent landfill for contaminated dirt, others represent sorting and processing facilities, water treatment, administration, etc..(Credit: Env. Ministry)

From the start the problem of where to put soil, plant matter, and other debris removed in the process of decontamination has posed great difficulties. More than one expert we spoke with in 2011 suggested that it made the most sense to deposit it in the most contaminated areas, where it would neither increase the overall radiation levels, and, because these areas were expected to be closed to human habitation for a long time, would pose the least additional risk to people. In effect a plan which accomplishes this has gone forward, but as with almost every aspect of post-disaster recovery, it has been fraught with difficulty and delays.

Environment Ministry explanation of interim storage plan, 2014 (in Japanese):
http://josen.env.go.jp/material/pdf/dojyou_cyuukan.pdf

Currently, decontamination debris is stored in large bags stacked in large mounds in about 75,000 locations across Fukushima, where they now form a familiar part of the landscape of nearly every town. The government has rented these temporary storage plots from the landowners, in most cases with the stipulation that the debris would be removed within 3 years, at which point an "interim" storage site, where the debris would be processed and kept for 30 years, was expected to be ready. A 16 sq. km site, roughly the same size as Haneda Airport, surrounding Fukushima Daiichi and straddling the evacuated towns of Futaba and Okuma, has been selected, and detailed plans completed. While the prefectural and local governments have approved the plan, landowners have been reluctant to sell their land, and only 0.4% of the necessary land (0.6 sq km) has been

secured for use. Contact information for only roughly half of the 2365 landowners has been determined, and most of those who have been approached have refused so far. Regardless, the first test hauls of soil were scheduled to begin on March 13, 2015. 43,000 cubic meters of soil, about 0.2 % of the total that needs to be moved, are expected to be carried in during the first year as transportation tests.

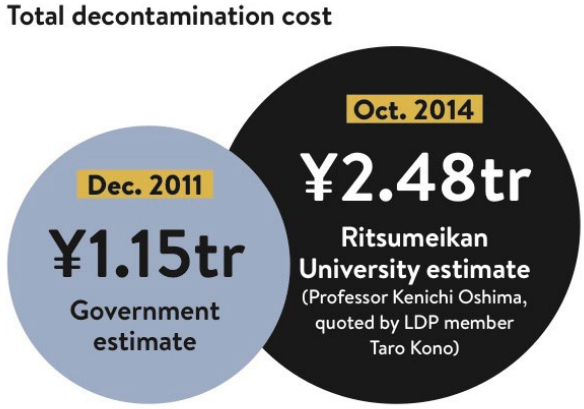
Fukushima Minpo News: Construction work begins for interim nuclear waste storage in Futaba, Okuma towns, Feb. 4, 2015

http://the-japan-news.com/news/article/0001978747

http://www.fukushimaminponews.com/news.html?id=466

When completed, the interim storage site will include covered landfill for contaminated soil, constructed differently for soil above and below 8000 Bq/kg; "volume reduction" facilities, a euphemism for incinerators to reduce tree branches and other burnable debris to ash, which can be more easily stored; secure concrete storage buildings for casks filled with waste over 100,000 Bq/kg, such as the incineration ash; water purification facilities for groundwater that might be affected; sorting facilities; and administration and other buildings. When in full operation, this will be a very, possibly unprecedentedly, large landscape devoted to radioactively contaminated waste. Nevertheless, upon examining the proposed plans, technical experts we have consulted have said that the facilities represent the state of the art and reflect a high consideration being given to safety and minimizing further consequences to the environment. Safecast has been establishing a network of fixed, realtime radiation sensors in Fukushima and elsewhere, and believe this site should have robust third-party monitoring of both air and water. Further, no consensus has been reached about what to do with the debris after the specified 30 years have elapsed. Some proposals, such as to send it to other prefectures to be used in land reclamation and road construction, are certain to face enormous public opposition. On the other hand, it is difficult to predict what public sentiment might be like, and what technological options might be available, 30 years from now.

– Decontamination cost estimates:



(Credit: FCCJ; graphic by Andrew Pothecary)

It is challenging to find up-to date information on costs for most aspects of the disaster. Several different agencies as well as TEPCO each prepare their own budgets and provide summaries, but determining how much money various agencies provide to each other and to Fukushima Pref., for instance, is extremely difficult.

In March 2014 NHK compiled estimates from the govt and TEPCO and provided a summary of expected total costs, including ¥2.5 trillion for decontamination:

http://www3.nhk.or.jp/news/genpatsu-fukushima/20140311/1516_songaigaku.html

These figures are fairly close to others compiled by Prof. Oshima of Ristumeikan Univ, in October 2014, ¥2.48 trillion, quoted in this article by former PM Kono Taro:

http://www.huffingtonpost.jp/taro-kono/cost-of-nuclear-plant_b_6000754.html

These can be compared to the early estimate of ¥1.15 trillion released in Dec 2011 by the Cabinet Office:

http://www.cas.go.jp/jp/seisaku/npu/policy09/pdf/20111221/hokoku.pdf

Finally, in Feb., 2015, Environment Ministry staff in Fukushima told us that the official cost estimates were:

-- ¥2.5 trillion for decontamination

-- ¥1.1 trillion for the interim storage site

(Our thanks to Antonio Portela for assistance in compiling this data)

—Travel in the area

—Rte 6 reopened

Since shortly after the start of the accident, a 14 km section of Route 6, which passes through the towns of Tomioka, Okuma and Futaba in the "Difficult to return" evacuation area near the Daiichi plant, had been closed to normal traffic, but was reopened at midnight on Sept. 14, 2014. Prior to this, people wanting to travel from Iwaki and other towns on the coast to the south of the plant, to Minamosoma and other towns north of it, were forced to take a long detour to the west that required three or more extra hours of driving. The reopening of this stretch of road has made north-south travel through the coastal part of the prefecture immensely easier. Side roads remain closed except for people with necessary permits, and due to a higher risk of radiation, people are not allowed on this stretch of road on motorcycles, bicycles, or on foot. Safecast volunteers soon uploaded data from the area showing dose rates over 5 uSv/hr..

http://www.fukushimaminponews.com/news.html?id=406

—Joban expy open

The Joban Expressway runs close to the coast from Saitama Prefecture through Tohoku. Nearly complete at the time of the disaster, a 14.3 km section in Fukushima between Tomioka and Namie remained undone, and work on it essentially came to a standstill due to radiation risks and other priorities. The final section was opened for public use on March 1, 2015. Decontamination and construction techniques intended to reduce doses to travelers were implemented; Safecast volunteers logged radiation levels over 7 uSv/hr soon after it was opened.

http://blogs.wsj.com/japanrealtime/2015/02/19/highway-to-open-near-fukushima-nuclear-plant-no-exits-allowed/

http://the-japan-news.com/news/article/0001972046

— Rail lines

Prior to the disaster, primary coastal rail service in Fukushima was provided by JR East's Joban Line, which connected Ueno Station in Tokyo to the Tohoku region. Service on this line has been restored except for a section between Tatsuta and Haranomachi, which runs through the "Difficult to return" evacuation zone (including the towns of Tomioka and Namie), and one between Hamayoshida and Komagamine, further north of the plant near the town of Soma. Inspections and repair work are currently underway to restore service to all but the section between Tomioka and Namie. A bus service was begun between Tatsuta and Haranomachi on Jan 31, 2015. Meanwhile, Tomioka Station, which had stood in a partially destroyed, overgrown state since 2011 and has drawn many journalists and visitors, was dismantled in March 2015.

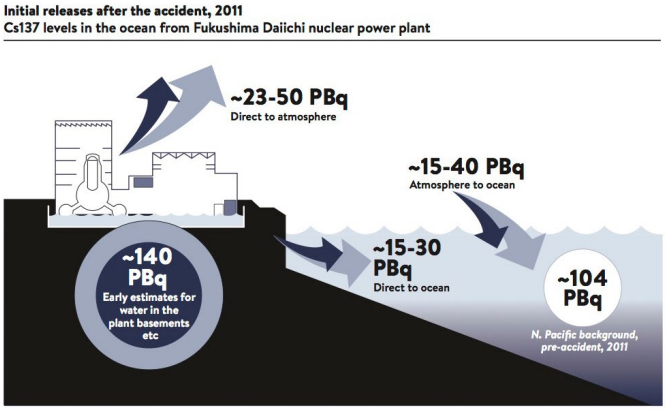
Other rail service in Fukushima has been restored.

http://www.jrmito.com/eq/index.html

http://www.jreast.co.jp/pdf/damage03.pdf

http://www.jrmito.com/press/120927/20120927_press.pdf

2.3.3—The Ocean



(Credit: SAFECAST; graphic by Andrew Pothecary)

The radioactive releases to the ocean were huge, but not really unprecedented. Many teams of oceanographers have been tracking and sampling the nuclides as they make their way across the Pacific, and predictions they made two years ago about how long it would take the ocean "plume" to reach the coast of North America, and how much cesium would be in it when it got there, have proven to be very accurate. As predicted, the levels are very low, lower than in the 1970's for instance. But the plant is still leaking and major releases of contaminated water cannot be entirely ruled out. Meanwhile, the radioactive contamination on the seabed off the Fukushima coast has been mapped, and experts agree that only time will reduce the ongoing impact on marine species there, including many dining table mainstays. Close monitoring of the ocean environment is extremely important and will continue to be for years to come.

2.3.3.a—Measurement overview

Since most of the radioactive releases from Fukushima Daiichi ended up in the ocean, either as fallout from the air or directly through contaminated water leaking from the site, close monitoring of the ocean environment is extremely important and will continue to be for years to come. Because there have been large previous releases of radioactivity to the ocean, such as from nuclear weapons testing, from the Chernobyl accident, and from nuclear sites such as Sellafield in the UK, as more data has been gathered since 2011 it is becoming possible to make reasonable comparisons. Oceanographers from several countries have been monitoring radiation levels in the ocean for decades, since well before the Fukushima disaster, and their historical data and understanding of how these materials disperse through the ocean environment is crucial to our understanding. Oceanographic survey teams sprang into action soon after the start of the accident, and the hard data they have collected since then has helped fill in gaps in knowledge about the quantity and composition of the radioactive releases, and to predict the levels of radioactivity that will reach other countries around the Pacific rim, and when. Future large releases are not out of the question, however, so while the situation is steadily improving now, there are imaginable scenarios in which it could possibly become worse again.

Table 1. Summary of cesium-137 sources to the environment and ocean in PBq (10^{15} Bq)

Source	Total[a]	Total Ocean[b]	2011 Ocean[c]	2011 North Pacific[d]
Global fallout	950	600	190	76
Close-in fallout	180	180	56	28[e]
Total fallout				104
Chernobyl	100	18[f]	10	n/a
Sellafield	39	39[g]	30	n/a
La Hague	0.96	0.96[h]	0.75	n/a
Fukushima				
Atmospheric				10–15[i]
				23–50[j]
Direct Ocean				3.6–5.9[k]
				11–18[l]
				12–41[m]
Total Fukushima				4–90

a. Cumulative total for given source at time of reference. From Aarkrog (2003) unless otherwise noted
b. Total deposited on the ocean
c. Total ocean decay corrected to 2011
d. Fraction of ocean input between 0 and 90°N in Pacific Ocean
e. Aarkrog (2003) assumed 50% of Pacific Proving Ground fallout deposited north of equator. Close-in fallout from other sources considered negligible (at least for North Pacific)
f. 10–20% of Chernobyl fallout fell into ocean, primarily North, Baltic, Black, and Mediterranean Seas in 1986
g. Sellafield discharges directly to Irish Sea. Peak in 1974
h. La Hague discharges to English Channel. Peak in 1971
i. Chino et al. (2011); Morino et al. (2011)
j. Stohl et al. (2011)
k. Miyazawa et al. (2012); Tsumune et al. (2012); Kawamura et al. (2011); Estournel et al. (2012)
l. Charette et al. (2013); Rypina et al. (2013)
m. Bally du Bois et al. (2012)

Comparison chart of large historical radiation releases to the ocean, by researcher Ken Buesseler of WHOI.(Credit: Buesseler, 2014. Fukushima and Ocean Radioactivity. Oceanography 27(1),)

Some reliable estimates of Cs-137 levels in the ocean for comparison are (not including Sr-90 or other nuclides):

N. Pacific 2011 (pre-accident), remaining from testing:
76 PBq

Initial Fukushima releases:

Fukushima to atmosphere (high estimate, Stohl et al)
23-50 PBq

Fukushima atmos to ocean (Aoyama, 2013)
15 PBq

Fukushima Direct to ocean, most common estimates
15-30 PBq

Ongoing water releases:

From rivers per year (Buesseler, 2012)
less than 0.012 PBq

From groundwater per year (Aoyama, 2013)
0.01 PBq

10 years at these rates combined:
0.22PBq

Highly contaminated water in the lower levels of the power plant (rough estimates):

(Nishihara, 2011, Ebisawa, 2012):
140- 276 PBq

It's worth comparing these to what has been released at Sellafield:

Sellafield to ocean total (mainly Irish Sea)
39 PBq

Sellafield to ocean 1975 (Norway gov. data) per year
5 PBq

Sellafield to ocean now per year
0.001 PBq

In the following sections we will briefly describe what recent survey data shows about radiation levels in the ocean and seabed within 100 km of Fukushima, and in the deep ocean beyond that.

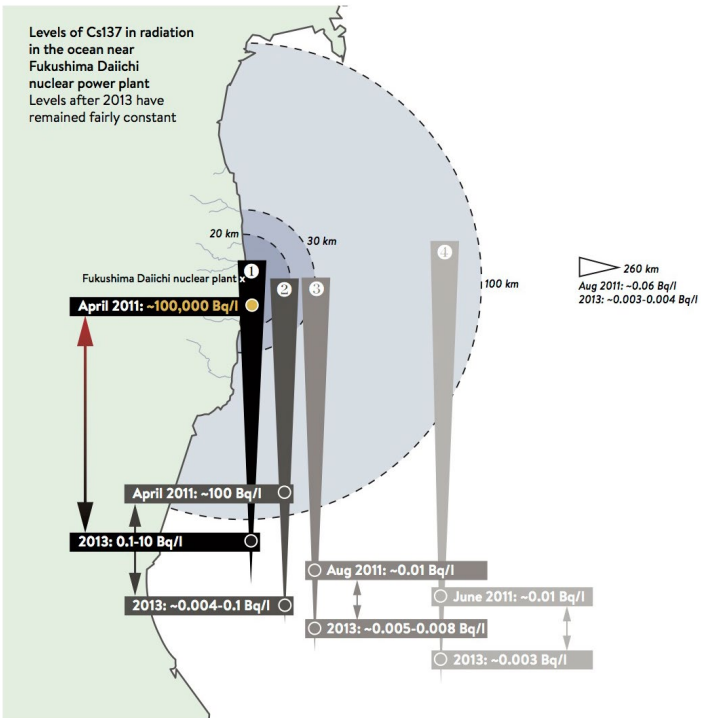
2.3.3.b—Within 100km

Most of the available data for waters within the 100 km zone is from Japanese government agencies, researchers working under Japanese government grants, or from TEPCO, but some independent surveys have also been done. There have been instances in the past of ocean researchers not being allowed to publish their Fukushima-related data, but none have come to light since 2012. When compared to independently collected data, measurements published by government agencies and by TEPCO have generally held up, and problems are usually ones of omission — locations for which data should be made available but is not. Regardless, we are gradually able to form a fairly clear picture of what is happening both in the water itself and on the seabed.

This detailed 2014 document from the Nuclear Regulation Authority of Japan (NRA), drawn up in conjunction with several other agencies, explains what is measured where, how frequently, and by whom:

Implementation Guides on Sea Area Monitoring April 01, 2014
http://radioactivity.nsr.go.jp/en/contents/9000/8404/24/274_s_20140401.pdf

Monitoring in the port area of Daiichi itself is done by TEPCO weekly. Samples are taken by TEPCO or a gov't agency from about 20 set locations within 2 km of Daiichi on a weekly basis in most cases; from about 30 locations within 20 km of on a weekly, biweekly, or monthly basis; and from about 30 locations within 100 km on a monthly basis, in addition to another 31 points immediately offshore of Fukushima Prefecture, on a monthly basis. Ocean sampling of nearby prefectures is done at intervals ranging from biweekly to once every 6 months, depending on location. In addition, about 10 points within 300 km are sampled once every 6 months, and another four within 1000 km are sampled yearly. Both seawater and seafloor sediment in Tokyo Bay, Sendai Bay, and areas off of the mouths of major rivers are also monitored several times a year.



Credit: SAFECAST; graphic by Andrew Pothecary

The following documents provide good graphs of how radiation levels in seawater have changed at several offshore sample points since March, 2011. To summarize the findings, within 20 km of Daiichi concentrations of Cs-124, Cs-137, and I-131 reached as high as 100,000 Bq/L in March 2011. The I-131 decayed and disappeared within a few months, while the Cs levels had dropped to approximately 10 Bq/L a year later. As the graphs show, since 2013 they have occasionally exceeded 10 Bq/L within 20km at some points, but have generally been 1 Bq/L or lower. At 20-30 km, and out to 100 km, since 2012 they have consistently been 0.01 Bq/L or less. Between 100-300 km, they have consistently been between 0.001 – 0.01 Bq/L.:

Change of the radioactivity concentration of the seawater in sea area close to Fukushima Daiichi NPS / coastal sea area (within 20 km)

http://radioactivity.nsr.go.jp/en/contents/8000/7742/24/engan.pdf

Change of the radioactivity concentration of the seawater in off-shore sea area (bet. 30-100 km)

http://radioactivity.nsr.go.jp/en/contents/8000/7745/24/okiai.pdf

Change of the radioactivity concentration of the seawater in outer sea area (bet. 100-300 km)

http://radioactivity.nsr.go.jp/en/contents/8000/7746/24/gaiyou.pdf

Recent results:

—Daiichi Port test results:

TEPCO's port water test results from March 13, 2015, show that cesium was detected at low concentrations (1.3-7.5 Bq/L) at 4 of the 8 sample points, and was undetected at the others. Tritium, maximum levels of 11Bq/L, was detected at 7 of the 8 points, and gross beta, maximum of 41 Bq/L, at 4 points. Water in the inner port (intake channel) is moderately higher, with consistent single or double digit detections of both Cs134 and Cs 137, tritium up to 460 Bq/L, and gross beta up to 140 Bq/L:

TEPCO: Analysis Results of Seawater Obtained around Fukushima Daiichi NPS March 24, 2015 Tokyo Electric Power Company (Inside of the Port of Fukushima Daiichi NPS)

http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/intake_canal_map-e.pdf

Analysis Results of Seawater Obtained around Fukushima Daiichi NPS March 24, 2015 Tokyo Electric Power Company (Inside of Unit 1–4 Water Intake Channel)

http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/2tb-east_map-e.pdf

Recent tests from the immediate vicinity outside the port show Cs undetected at all but 1 of 7 locations, up to 11 Bq/L of gross beta at two locations, and 1.7 Bq/L of tritium at one.
http://www.tepco.co.jp/en/nu/fukushima-np/f1/smp/2015/images/seawater_map-e.pdf

While these levels are currently quite low considering the ongoing contaminated water problems onsite, test results in this area frequently show higher levels. It is possible that TEPCO does not report sampling results from some locations which are more likely to give higher readings, and that occasional releases that happen during the intervals between testing may go undetected. The standard disclaimer that there is no independent verification of these results applies.

-- Test results between 2-100 km:

This NRA document from March 10, 2015 gives detailed recent test results for sample points between 2-100 km.

NRA: Sea Area Monitoring, March 10, 2015

http://radioactivity.nsr.go.jp/en/contents/10000/9539/24/Sea_Area_Monitoring_20150310.pdf

—Within 2 km: Cesium is either undetected or below 1 Bq/L at 12 sample points; similar for other nuclides.

—Between 2-20 km: Cesium is either undetected or below 0.1 Bq/L (most below 0.01 Bq/L) at 28 sample points; similar for other nuclides (at 11 samples points at which they were tested for).

—Between 20-100 km: Cesium is either undetected or below 0.01 Bq/L at 40 sample points, detected at below 0.1 Bq/L at one point; similar for other nuclides (at 11 samples points at which they were tested for).

—Seabed test results

As it does within watersheds on land, through biological and physical processes a portion of the cesium and other radionuclides in seawater eventually settles into sediment on the seabed. This is of concern primarily because it becomes bioavailable there to bottom-feeding species, such as flounder, as well as many filter feeders, such as shellfish, and remains in the foodchain. For this reason even in areas where most marine species show little or no radioactive contamination, bottom feeders might be high enough to be of concern. This has been borne out by seafood testing of fish caught near Daiichi. Monitoring of seabed sediment is therefore very important.

Currently seabed monitoring is being done by government agencies, by the Japan Coast Guard, and by other researchers. Not surprisingly these have revealed the existence of seafloor "hotspots" not unlike those on land, sometimes at a surprising distance from Daiichi itself. Excellent work is being done to map the radiation on the seabed, and to understand the processes by which undersea hotspots form.

—Seabed data from TEPCO

Recent seabed sampling by TEPCO of 43 locations, mostly within 20 km of Daiichi, show that while combined Cs-134 and Cs-137 levels at most sample points are below 100 Bq/kg, they reach as high as 800 Bq/kg at a handful of locations. As other sampling has shown, points on the seabed farther from the plant can be higher than those closer to it:

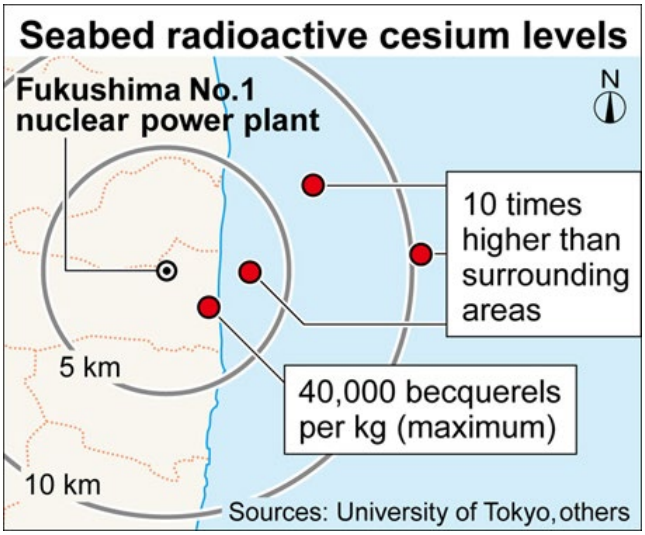
NRA: Distribution map of radioactivity in the marine soil around TEPCO Fukushima Dai-ichi NPP (Converted as dry soil) (Based on the press release of TEPCO) Sampling Date: Jan 5 — Jan 30, 2015

http://radioactivity.nsr.go.jp/en/contents/10000/9473/24/280_20150219.pdf

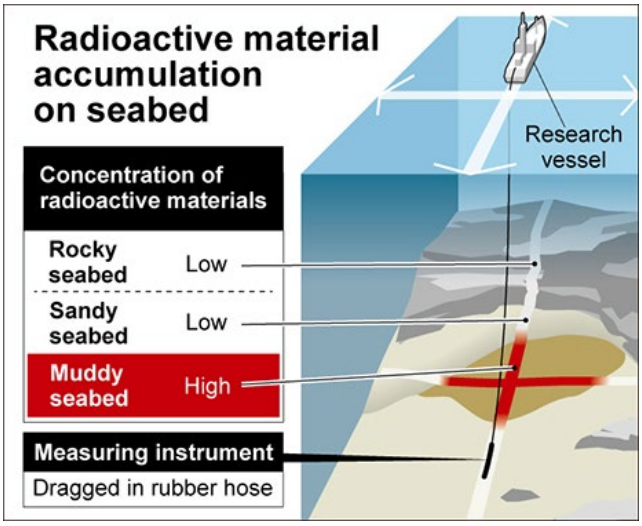
—Seabed data by ocean researchers:

Some of the most informative data on seabed radiation comes from a team of researchers from the University of Tokyo, the National Maritime Research Institute, and Kanazawa University, who used a newly developed towed gamma ray spectrometer to map radiation and seafloor topography in an offshore area of approximately 50 km by 25 km. While they found an average concentration of Cs-137 of about 90 Bq/kg, they found 20 locations 4km offshore which were over 1000 Bq/kg, and others 6 km offshore as high as 2000 Bq/kg. In addition, locations surveyed off the

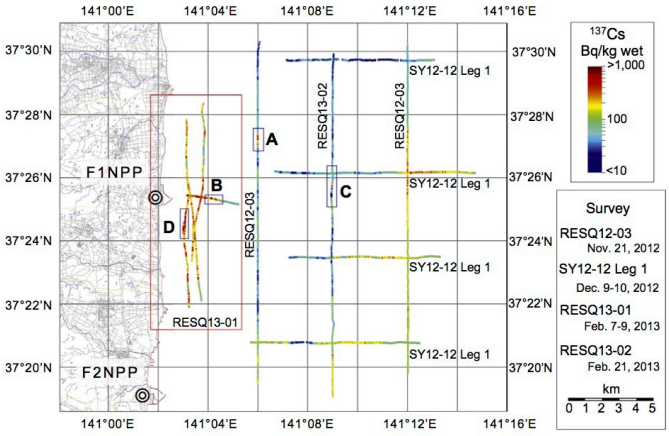
mouth of the Abukuma River in Miyagi showed 1300 Bq/kg (at 1.6 km) and 2700 Bq/kg (at 2.5 km). Previous studies have identified seafloor hotspots of a few hundred Bq/kg as far as 15 km offshore. These researchers determined that the hot spots occurred in places where the seabed has muddy depressions, as opposed to being sandy or rocky, and depends on particular patterns of current flow. The researchers also identified similar hotspots south of Daiichi, which they suspect is most likely due to cesium deposited there by currents during the first weeks of the accident.



(Credit: Asahi Shimbun)



(Credit: Asahi Shimbun)



Seafloor survey map showing undersea hotspots 15 km offshore (Credit:Thornton, et al, 2013)

Marine Pollution Bulletin: Distribution of local 137Cs anomalies on the seafloor near the Fukushima Dai-ichi Nuclear Power Plant (Thornton, et al, 2013)

http://www.sciencedirect.com/science/article/pii/S0025326X13003378

http://www.sciencedirect.com/science/article/pii/S0967063713000915

Seafloor sediment monitoring (Thornton, et al, 2013)

http://ocean.iis.u-tokyo.ac.jp/content/files/20131207_Radiation_Monitoring_Symposium_in_Fukushima.pdf

See also:

Biogeosciences: Spatiotemporal distributions of Fukushima-derived radionuclides in nearby marine surface sediments (Kusakabe, et al, 2013)

http://www.biogeosciences.net/10/5019/2013/bg-10-5019-2013.pdf

—Seabed data from the Japan Coast Guard:

The Japan Coast Guard has been monitoring seawater nuclides since 1959, and seabed nuclides since 1973, and have released post-accident data for surveys done in 2011, 2012, and 2013. The seabed sampling focuses on important coastal cities, but there are no sampling points close to shore between Tokyo and Sendai, and so no coastal sampling for Fukushima (though they sample water at several points further out to sea). They give almost no interpretation of their findings, but simply report the levels and whether changes were detected compared to previous years.

The Coast Guard regularly samples 8 seabed locations. In their 2013 survey, Cs-137 was detected at all 8, all of which had less than 10Bq/kg concentrations, except for Tokyo which had 55 Bq/kg, and Sendai which had 246 Bq/kg. Cs-134 was detected only at Sendai (107 Bq/kg), Tokyo (22 Bq/kg), and Niigata (2.5 Bq/kg). The implication is that the Cs-137 in places where no Cs-134 was found is not from Fukushima but predates it, and is probably left-over from nuclear testing or Chernobyl. It should be noted that overall the Cs levels in the seabed off Japan are higher than they were in 2011, and have declined slightly since 2012. This reflects the process of continued deposition from rivers which feed into Tokyo and Sendai bays, which has been confirmed by other researchers. On the other hand, the Coast Guard data also shows that Cs levels in seawater spiked in 2011 and quickly declined afterward. Radiation in the seawater at the points sampled is generally lower than at anytime prior to 2002.

Sr-90 was also detected at all seabed sample points, in the range of 0.020 – 0.099 Bq/kg, an order of magnitude lower than it was immediately following the Chernobyl accident. This makes it difficult to say what proportion of it is due to Fukushima. Most specialists agree that the Sr-90 currently being detected is most likely primarily residual, leftover from nuclear tests and the Chernobyl accident.

The Japan Coast Guard reports (in Japanese) can be found here:

Top page:

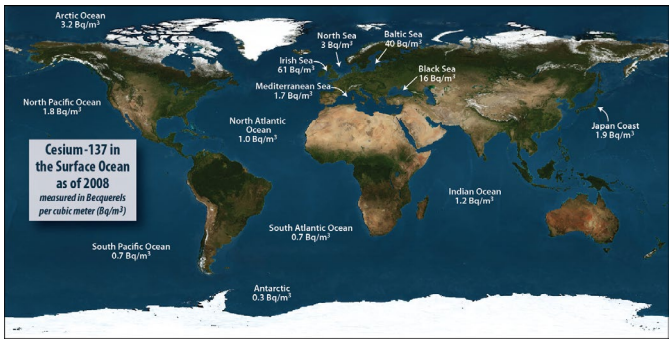
http://www1.kaiho.mlit.go.jp/KANKYO/OSEN/housha.html

2011:
http://www1.kaiho.mlit.go.jp/KANKYO/OSEN/housha/ho2011.pdf

2012:
http://www1.kaiho.mlit.go.jp/KANKYO/OSEN/housha/ho2012.pdf

2013:
http://www1.kaiho.mlit.go.jp/KANKYO/OSEN/housha/ho2013.pdf

2.3.3.c—The wider Pacific:



Cs-137 levels in the world's oceans as of 2008, prior to the Fukushima disaster (Credit: WHOI)

A lot of attention has been given to the potential effects of Fukushima radiation in the Pacific Ocean as a whole, and on the west coast of North America in particular. SAFECAST published a lengthy report about this on our blog in January, 2014, most of which is still applicable, and has been confirmed by more recent findings. It gives citations for many relevant studies, and we recommend that interested readers consult it:

Fukushima Across the Pacific
http://blog.safecast.org/2014/01/fukushima-across-the-pacific/

As we said at the time, several teams of ocean scientists have been closely monitoring the progress of the ocean "plume" as it crosses the Pacific. These scientists reached a consensus in 2012-2013 that the the Cs-137 levels in the waterborne Fukushima radiation now reaching the North American Pacific coast will peak at between about 0.004 and 0.010 Bq/L, compared to about 0.001-0.002 Bq/L before the accident, will stay that way for a few years, and should start declining again around 2017. Percentage-wise this means it will be 2 to 10 times the pre-existing Cs levels, which we could consider is a lot, especially since the entire Pacific will be affected.

While Fukushima released quite a lot of Cs-137 to the oceans, the amount appears to be comparable that from Chernobyl, about 1/10 of that from global testing, and only a tiny fraction of the natural radiation (mainly Uranium 238 and Potassium 40) that has always been there.

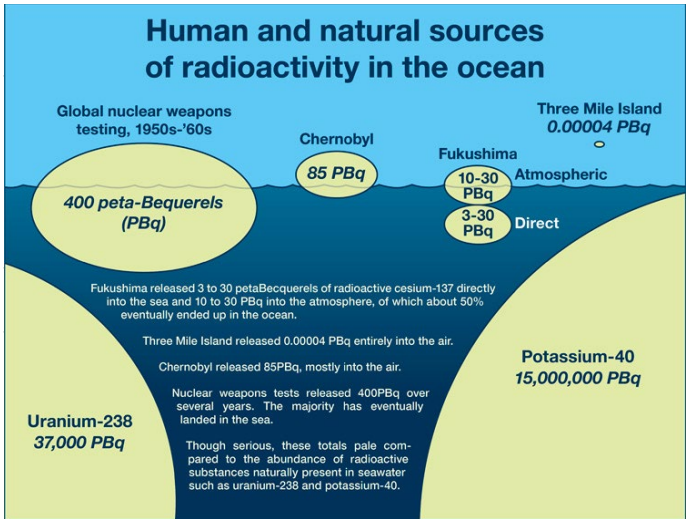


Diagram showing relative magnitudes of radioactive releases to the ocean (Credit: WHOI)

As a press release from the Woods Hole Oceanographic Institute pointed out, "This is an evolving situation that demands careful, consistent monitoring to make sure predictions are true."

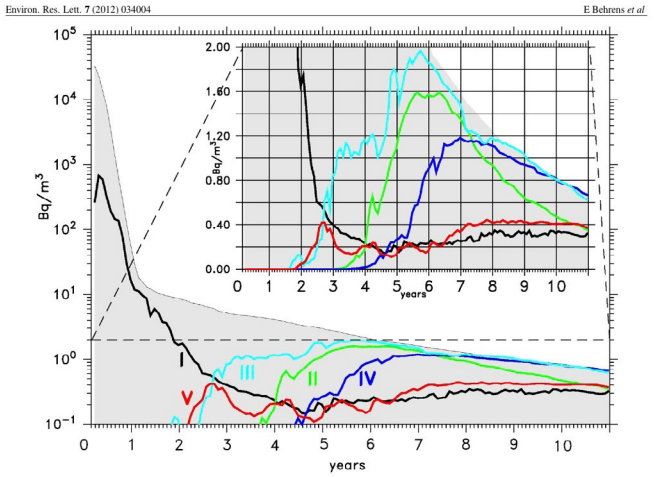


Figure 7. Temporal evolution of absolute peak concentrations (in Bq m^{-3}, logarithmic scale; grey shaded) and within individual regions (see figure 4(d)) from the 0.1°-model simulation, assuming a total input of 10 PBq of ^{137}Cs. Regions: western Pacific (I, black), off North America (II, green), Hawaii Islands (III, light blue), off Baja California (IV, blue), Aleutian Islands (V, red). The inset is a zoom into the part of the figure with levels below 2 Bq m^{-3} (pre-Fukushima values) on a linear scale.

Graph showing predicted levels of Cs-137 in the Pacific over a decade. Black represents the western Pacific; green: North America; light blue: Hawaii; blue: Baja California; red: Aleutians.(Credit: Behrens et al, Model simulations on the long-term dispersal of 137Cs released into the Pacific Ocean off Fukushima, 2012)

A very good study published in Feb. 2015 by scientists associated with Canada's Department of Fisheries and Oceans describes the movement of the Fukushima ocean plume (technically called a "radioactivity signal") across the Pacific, and its current status:

They conclude:

—It arrived at a sample point 1,500 km west of British Columbia, Canada, in June 2012.

—It had spread onto the Canadian continental shelf, i.e., close to but not reaching the coast, by June 2013.

—By February 2014, it had increased to a value of 2 Bq/m3 (0.002 Bq/L) throughout the upper 150 m of the water column, resulting in an overall doubling of the pre-existing fallout background from atmospheric nuclear weapons tests.

—The total levels of Cs-137 off the North American coast will likely reach maximum values of 3–5 Bq/m3 (0.003- 0.005 Bq/L) by 2015– 2016, similar to the levels that existed there during the 1980's.

— By 2021 the levels will decline and become closer to the pre-Fukushma fallout background of about 1 Bq/m3 (0.001 Bq/L).

This research also confirms that the best predictions made by others in 2012-2013 have been on the whole very accurate.

Arrival of the Fukushima radioactivity plume in North American continental waters Smith et al, 2015

http://www.pnas.org/content/112/5/1310.full.pdf+html?sid=75d02d2e-9507-43e2-af15-bd1a70b5b68a

—Good sources of information about ocean radiation:

Dr. Ken Buesseler and his team at Woods Hole Oceanographic Institution (WHOI) were some of the first researchers to monitor Fukushima radiation in the ocean, and to try to effectively inform the wider public about what was happening. The WHOI website has several informative articles about the issue:

WHOI Oceanus: Special feature, "Fukushima and the Ocean," 2013

http://www.whoi.edu/oceanus/series/fukushima

WHOI: FAQ: Radiation from Fukushima, last updated August 26, 2014

http://www.whoi.edu/page.do?cid=94989&pid=83397&tid=3622

WHOI Oceanus: How Is Fukushima's Fallout Affecting Marine Life? May 2, 2013

http://www.whoi.edu/oceanus/feature/how-is-fukushimas-fallout-affecting-marine-life

WHOI Oceanus: Radioisotopes in the Ocean: What's there? How much? How long? May 1, 2013

http://www.whoi.edu/oceanus/feature/radioisotopes-in-the-ocean

In addition, WHOI began a citizen science program to sample water on the Pacific coast of North America and elsewhere, called **"Our Radioactive Ocean."** The program has been extremely successful so far, and the results of dozens of samples taken by individuals and groups who have supported the project can be seen on the project website:

http://www.ourradioactiveocean.org

Another excellent source of information is the Fukushima INFORM website, which has very informative and up-to-date summaries of recent scientific findings compiled by Dr. Jay T. Cullen of the University of Victoria in British Columbia. The INFORM project is also citizen science based, and is building a network of volunteers to collect monthly samples for the next three years, which will be analyzed at university laboratories, and will help us understand the arrival and intensity of the Fukushima contaminated seawater plume. The project includes both seawater and biota.

Fukushima INFORM top page

http://fukushimainform.ca

More Citizen Science Seawater Monitoring Results: No Fukushima Contamination Detected, Feb. 16, 2015

http://fukushimainform.ca/category/results/

Monitoring Results For Sockeye Salmon and Steelhead Trout Collected Summer 2014, Dec. 1, 2014

http://fukushimainform.ca/2014/12/01/monitoring-results-for-sockeye-salmon-and-steelhead-trout-collected-summer-2014

—Summary:

Because the bulk of the radioactive releases from Fukushima ended up in the ocean and not on land, they have been less directly bioavailable for humans than ground contamination has been. The store of historical knowledge and experience about marine radioactivity which oceanographers have been able to provide also works in our favor, in terms of monitoring changes and predicting effects. The ocean is a very complex set of systems, and is imperfectly understood, but we feel the challenges are greater on land where food is grown and most people actually live. Also, the way radionuclides quickly disperse in the ocean stands in marked contrast to how they are actually stored and recycled in forest environments. In that sense, and in many others, we were lucky. But there's no room for complacency.

Looking at the big picture, the continuing releases from Daiichi to the ocean are a concern, but don't add much to the overall total released to the ocean by the accident so far. While the continuing releases are notable and need to be stopped, as the data at the beginning of this section suggests, even after several years at the current rates they will probably add less than 1% to what the initial releases dumped. Meanwhile, researchers like Buesseler, Kanda, and Aoyama have done a good job of describing how even the current continuing release levels have kept bottom feeders within a few km of the plant more contaminated than they would be without it, and how they keep even fairly distant seafloor hotspots hot. It's a real and measurable consequence, but at the same time the continuing releases don't noticeably affect, for instance, the overall amount and timing of the contamination spread across the Pacific.

Fishing for Answers off Fukushima, Buessleler: 2012 (paywalled)
http://www.sciencemag.org/content/338/6106/480

Another more recent paper brings together a wide variety of data on concentrations of Cs-137 and Sr-90 in seawater and marine life to illustrate the changes these have undergone since March 2011, and the possible implications:

Fukushima radionuclides in the NW Pacific, and assessment of doses for Japanese and world population from ingestion of seafood, Povinec, Hirose: 2015

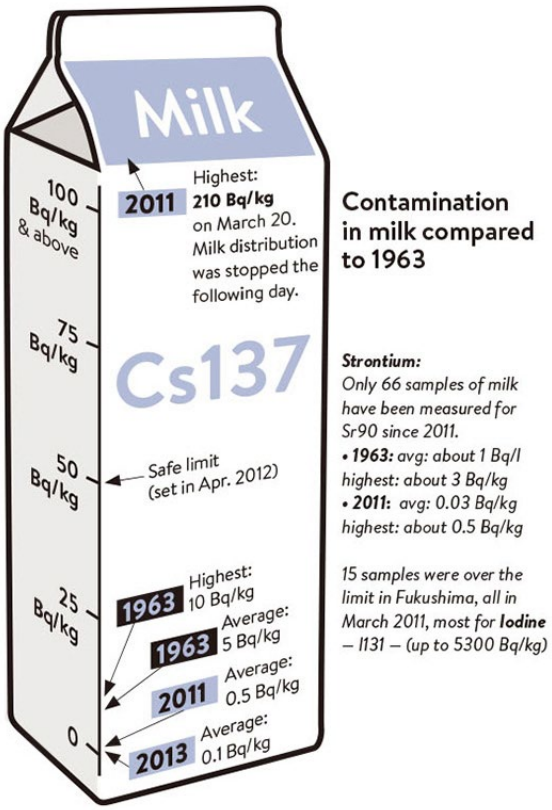
http://www.nature.com/srep/2015/150312/srep09016/pdf/srep09016.pdf

Again, in terms of effects on the Pacific ocean, the best research suggests that while they're not fully comparable, nuclear testing and the range of effects seen then is the closest overall precedent to Fukushima scale-wise, though while the testing almost certainly dumped several times more radiation in total than Fukushima did, it was also spread out over decades instead of all at once. Fukushima also resulted in extremely high concentrations near Japan in March-April 2011 that have only a few historical parallels in the contamination from testing, such as from Pacific surface tests.

Because of the way it's often discussed, this will seem counter to conventional wisdom, but if we go by the data, in terms of direct discharges to the ocean Fukushima is of a similar magnitude to Sellafield, and possibly less severe. Because of this Sellafield will probably provide the most applicable lessons about damage to the ocean environment, with the caveat that the Irish Sea is very different from the Pacific in terms of currents and ecosystem.

We'd also like to point out that the emergence of two very well organized citizen science projects for monitoring ocean radiation, "Our Radioactive Ocean" and "FukushimaINFORM," is some of the best news to come out of the disaster. There are citizens-based projects in Japan for monitoring food contamination and ambient doses in residential areas, but so far we have not seen any similar efforts emerge for forests, watersheds, or other ecological zones. The professional researchers investigating these areas are overextended and overworked, and we would like to encourage them to seek out citizen scientists to share the load, and for citizens to look for such opportunities.

2.4- FOOD



(Credit: FCCJ; graphic by Andrew Pothecary)

Keeping contaminated food off the market is essential for minimizing internal exposures to radiation. This risk is chronic because cesium and other radionuclides remain in the environment for years — decades in many cases — usually migrating deeper into the soil, and even if the problem appear to be controlled at some point, it is still present. The Japanese government quickly instituted a food monitoring program in March 2011, and in scale and comprehensiveness it has been unprecedented. Not everything is checked, however, which is why the appearance of dozens of independent, citizens-run food testing labs all over the country is extremely welcome. Also welcome are independent tests of actual meals being eaten by residents of Fukushima and elsewhere. While the relative paucity of tests for strontium remains a matter of concern, the independent tests tend to support official findings, that less that 1% of the food being produced in Fukushima has above-limit concentrations of cesium, and virtually none of this is finding its way onto the market. Farmers themselves deserve almost all the credit for this. The biggest food risks — wild mushrooms and vegetables, and wild boar and other game — are well known, and will continue to pose problems for years to come.

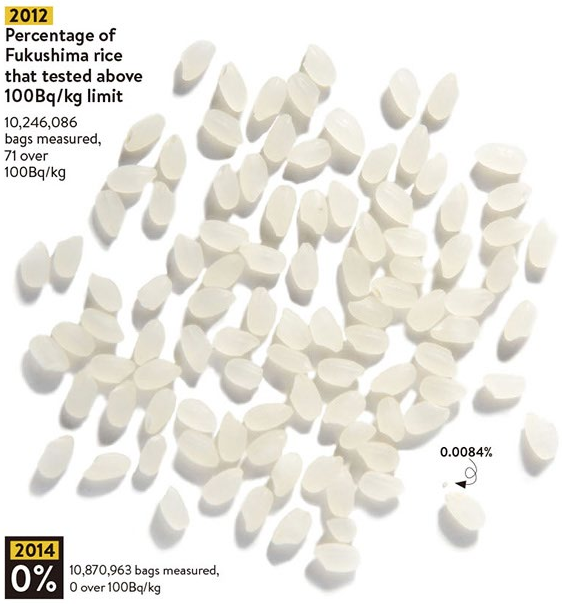
One of the biggest concerns in the wake of the Fukushima NPP disaster has been the effect of radioactive contamination on the food supply. As explained in the section on internal contamination screening, if not dealt with effectively, radioactive contamination in the food chain chain can easily lead to chronic internal contamination in a large proportion of the population, as it has in the Chernobyl area. The goal, of course, is to minimize or even eliminate this risk in the entire population if possible. The past four years since the Fukushima accident have greatly increased our knowledge of what steps and methods, in farm fields, in fisheries, in testing labs, and in terms information provided to the food supply chain as well as to consumers, can best help reduce radiation exposures to the public from food. At this point, when taken together, the food testing data, both official and independent, and the internal contamination screening data, both official and independent, indicate that the measures have been very effective overall, much better than in the Chernobyl region, for comparison. But these exposures are not yet eliminated entirely, nor are they likely to be for some time. Also, it is important to acknowledge that we do not have a clear picture of people's internal exposures overall during the first months of the disaster.

For agricultural products, while financial and technical government assistance has been essential, most of the credit for the success seen so far is due to the farmers themselves, who have studied, tested, destroyed entire crops, tried new soil treatments, replanted, tested, and so on for several years, until they could grow food they themselves were willing to eat and sell. The process is not perfect. Though the Japanese government standard for cesium contamination in food, at 100 Bq/kg, is the lowest in the world, it's important to note that many farmers in Fukushima, as well as in Tochigi and other affected places, have taken it upon themselves to only sell food that is well below that. We understand the position taken by many people and groups that no cesium or other radioactive contamination in food is acceptable. People absolutely have a right to uncontaminated food. Nevertheless we believe that everyone involved has been making sincere efforts to reduce the contamination in Japanese food to the lowest possible levels.

We give a basic summary of findings immediately below, followed by more in-depth information.

2.4.1 — Basic findings

2.4.1a - Rice:



(Credit: FCCJ; graphic by Andrew Pothecary)

Since 2012, every bag of rice produced in Fukushima Pref. has been tested for radioactive cesium. Since 2012, the rate found over limit (100 Bq/kg) has been less that 0.01%. In the past year, as of March 18, 2015, none of the 10.9 million bags of rice tested was over the 100 Bq/kg limit. This is a remarkable achievement and deserves to be applauded, especially because it is due primarily to the efforts of farmers.

2012: 10,246,086 bags measured,
71 over 100Bq/kg (0.0084 %)

2013: 11,006,534 bags measured,
28 over 100Bq/kg (0.0003%)

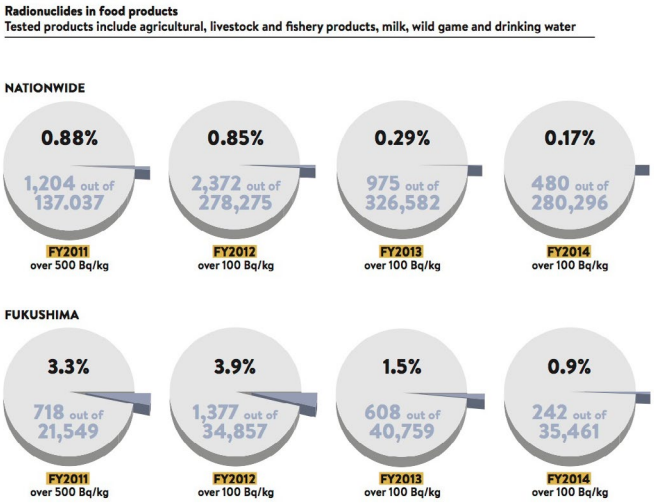
2014: 10,966,597 bags measured,
0 over 100Bq/kg (0%)

(as of March 18, 2015)

In 2014, however, it should be noted that 1909 bags (0.02%) had between 25-50 Bq/kg; 11 (0.0001%) had between 51-75 Bq/kg; and 1 bag (0.00001%) had between 76-100 Bq/kg.

Source: Fukushima Prefecture food test information, rice:
https://fukumegu.org/ok/kome/

2.4.1b - Food products in general:



(Credit: SAFECAST; graphic by Andrew Pothecary)

Government test results indicate that the amount of cesium-contaminated food being produced in Fukushima and nationwide has steadily decreased since 2011, and is currently about 1% of the total in Fukushima, and 0.1% nationwide. People are generally surprised to learn that in Fukushima in 2012 it was only about 4%. These overall figures don't tell the whole story, however, and details follow below.

Nationwide results:

FY2011: 137,037 items tested:
1,204 over 500 Bq/Kg (0.88%)

FY2012: 278,275 items tested:
2,372 over 100 Bq/Kg (0.85%)

FY2013: 326,582 items tested:
975 over 100 Bq/Kg (0.29%)

FY2014: 280,296 items tested:
480 over 100 Bq/Kg (0.17%)

Fukushima results:

FY2011: 21,549 items tested:
718 over 500 Bq/Kg (3.3%)

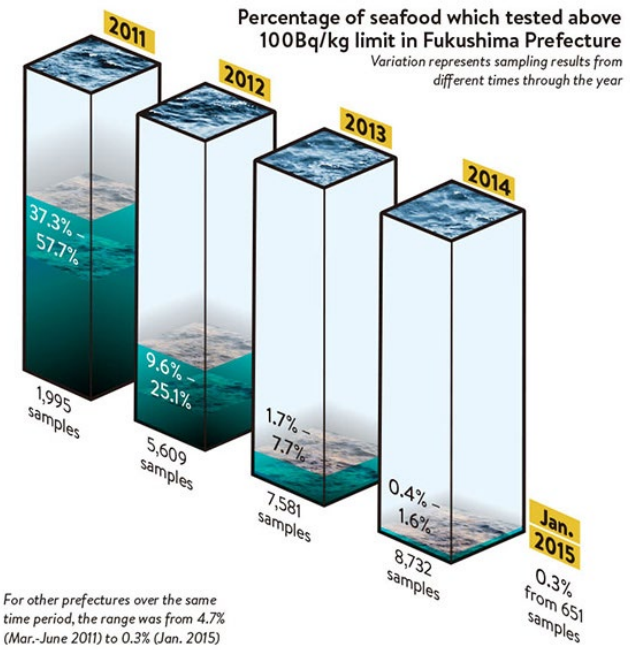
FY2012: 34,857 items tested:
1377 over 100 Bq/Kg (3.9%)

FY2013: 40,759 items tested:
608 over 100 Bq/Kg (1.5%)

FY2014: 35,461 items tested:
242 over 100 Bq/Kg (0.9%)

Source: Ministry of Health, Labor, and Welfare (MHLW) food test results, with breakdowns by prefecture and food type: http://www.mhlw.go.jp/english/topics/2011eq/index_food_radioactive.html

2.4.1c - Seafood:



(Credit: SAFECAST; graphic by Andrew Pothecary)

A lot of testing focuses on fish, or more specifically, on "fisheries products," which includes shellfish, octopus and squid, as well as seaweed and a few other items. The number of items being tested was steadily increased through 2014. Coastal and trawl fishing off Fukushima Prefecture are still banned, except for experimental fishing for the purpose of providing items to test.

Percent of seafood from Fukushima over 100 Bq/kg:

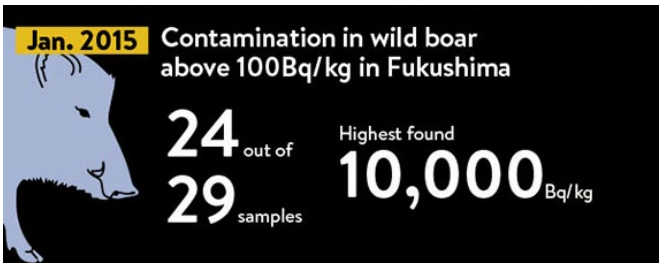
April-June 2011: 57.7%
April-June 2012: 21.6%
April-June 2013: 4.6%
April-June 2014: 1.0%
Jan-Feb 2015: 0.2%

Nationwide: 1% or less have been over limit since mid-2012, and none since Oct. 2014.

Source: Fisheries Agency of the Ministry for Agriculture, Forestry, and Fisheries testing results:

http://www.jfa.maff.go.jp/e/inspection/index.html

2.4.1d - Greatest risks:



(Credit: FCCJ; graphic by Andrew Pothecary)

Certain wild plants and animals gathered or hunted as food are known to present the highest risk of contamination from cesium. Plants that people in contaminated areas have been advised to avoid include wild mushrooms, as well as bamboo shoots, wild berries, and several other varieties of edible plants. Wild boar is quite likely to be very contaminated, as is deer, bear, and many species of wild fowl. Freshwater fish living in lakes or ponds may show high cesium levels too. To date, individuals in Fukushima who have had the highest levels of internal contamination have been elderly people who have continued to eat these foods despite being advised against it. Also, it is not widely appreciated that many mushrooms and wild boar from prefectures other than Fukushima have tested over-limit for cesium.

2.4.1e - Consumer sentiment:

Despite what many of us consider the very low levels of contamination in food from Fukushima which is being sold, many people do not seem to be aware of it. The Consumer Affairs Agency of Japan has carried out surveys twice a year since 2013 to find out how many people are reluctant to buy food from Fukushima. About 17% of respondents from the survey done in 11 prefectures in Feb. 2015 said they are cautious about buying food produced in Fukushima, a rate slightly lower than last August (20%) but slightly higher than a year ago (15%). Only 21% knew that Japan's safety standards for radiation in food are stricter than in the United States or Europe, but 22.5% nevertheless felt they should be made stricter.

In addition, a recent study shows that there is a difference in attitudes towards eating Fukushima food within the prefecture itself. While about 75% of families in Minamisoma say they avoid Fukushima food, for instance, only about 20% of the families in Miharu, near Koriyama, do. Nevertheless residents of both towns have similarly low levels of detection of internal cesium; several years worth of internal contamination testing shows that avoiding food from Fukushima has not made the Minamisoma families detectably "safer." Based on the very large amount of good data that is available, it's difficult to say that avoiding Fukushima food has a clear rational basis at the moment, but it fulfills a different kind of need, namely providing a concrete step that a mother can take on behalf of her family to reassure them, as well as herself, that she is doing everything she can to keep them out of risk. Most of us agree that these people should not be told that they are wrong to do so.

Consumer Affairs Agency survey results (in Japanese)

http://www.caa.go.jp/safety/pdf/150310kouhyou_1.pdf

WSJ: Nearly One in Five Japanese Reluctant to Buy Fukushima Food, March 11, 2015

http://blogs.wsj.com/japanrealtime/2015/03/11/nearly-one-in-five-japanese-reluctant-to-buy-fukushima-food/

Whole body counter surveys of Miharu-town school children for four consecutive years after the Fukushima NPP accident, Hayano et al, 2015

http://arxiv.org/abs/1501.02637

2.4.2— Food: In-Depth

2.4.2a— Overview Of Japanese Government Food Monitoring

Food monitoring was implemented by the central government by March 17, 2011, under the jurisdiction of the Ministry of Health, Labor, and Welfare (MHLW), which has responsibility for food safety, and gradually expanded. The Ministry of Agriculture, Forestry and Fisheries (MAFF) also conducts separate inspections, particularly of seafood products. While farm products from seventeen prefectures, including Miyagi, Ibaraki, Tochigi, Gunma, Chiba, and Tokyo, are regularly inspected, outside interest is focussed on Fukushima. Nevertheless, during FY2011, only 15% of the samples tested by the government were from Fukushima; 12% were from Fukushima during FY2012, FY2013, and FY2014. The monitoring system is designed to interdict contaminated food before it reaches the market. Particularly in its early stages in 2011, the methods and selection criteria for what would be checked, when, and how were fairly opaque and difficult to ascertain, but even now after four years, the rationale sometimes remains somewhat obscure even to people who try to keep a close eye on the situation.

MHLW food safety info:

English main site:
http://www.mhlw.go.jp/english/

Index of test results and related information on policies, etc:
http://www.mhlw.go.jp/english/topics/2011eq/index_food_radioactive.html

MHLW main food test portal (Japanese):
http://www.mhlw.go.jp/shinsai_jouhou/shokuhin.html

Access to monthly press releases (Japanese):
http://www.mhlw.go.jp/stf/houdou/

MAFF also has test results posted online in English:
http://www.maff.go.jp/e/quake/press_110312-1.html

JAEA launched a new website early 2015 that includes data from other gov't agencies for different categories of food, as well as drinking water:

JAEA: Database for Radioactive Substance Monitoring Data

http://emdb.jaea.go.jp/emdb/en/

Produce, including rice, as well as meat and seafood, is generally tested on a town-by-town (municipality) basis. When an item, such as spinach, is tested in a particular town and found to exceed the government's 100Bq/kg limit for cesium 134 and 137 combined, for instance, all spinach from that town is embargoed and can't be sold. Produce from farms other than the one the sample came from are rechecked as well. Embargoed towns are allowed to sell the item again when it has passed several inspections (usually three, but the number varies according to the crop and season) within the span of a month. In addition, when an item is found to contain 50Bq/kg, that is, half the allowable limit, the frequency of inspections of that item is increased in that town. Some areas are released from embargo after a few months, while others have remained under embargo for certain food items, particularly wild mushrooms, mountain vegetables ("sansai"), and wild game, since 2011 or 2012. The actual regulations have changed a few times since 2011, and the most recent detailed information, as well as tables showing what items are inspected in which prefectures, can be found in a long MHLW press release from March 20, 2014, available here:

MHLW: The Revision of the "Concepts of Inspection Planning and the Establishment and Cancellation of Items and Areas to which Restriction of Distribution and/or Consumption of Foods concerned Applies", March 20, 2014

http://www.mhlw.go.jp/english/topics/2011eq/dl/food-140320.pdf

In addition, tables showing which items have been embargoed, where, and for what period, can be found in this document from March 10, 2015:

MHLW: The instructions associated with food by Director-General of the Nuclear Emergency Response Headquarters (Restriction of distribution in Fukushima Prefecture) March 20, 2015

http://www.mhlw.go.jp/english/topics/2011eq/dl/food_instruction_10March_2015.pdf

"Request for shipment restraint and other measures" as of February 3, 2014

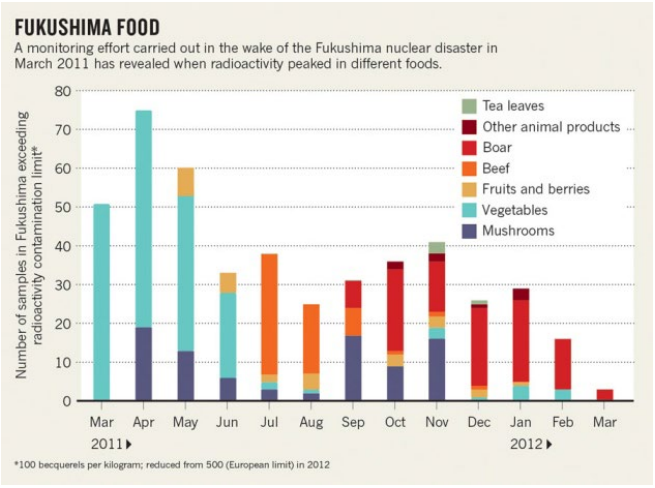
http://www.maff.go.jp/e/quake/press_since_130327.html

Our most informed colleagues agree that a lot of the public frustration about the obscurity and opacity of official information about food testing results stems from the fact that the food monitoring program was not designed primarily to inform the public about the contamination levels, but to prevent food which is over the limit from reaching the market. Consequently the program focuses mainly on the production side, and informing producers and distributors, as well as government officials, of the testing criteria for different localities, and of decisions such as distribution bans for specific municipalities or prefectures. Despite useful initiatives like a searchable database for Fukushima Prefecture food linked below, informing the public has been clearly secondary. We encounter the consequences of this frequently: there is no simple searchable government database of food test results for the whole country; the list of banned items is basically a table on a PDF which does not include a single map; most people still do not understand what the contamination limits actually mean; and most people are not aware that there are hundreds of items in Fukushima that have consistently been under the detection limits for contamination for four years, and quite a few items outside of Fukushima which frequently test over-limit.

It's not only regular citizens whose understanding is hampered by the poor communication until now. Some official overseas agencies apparently have not fully understood the Japanese food testing policies or results. In 2012, the WHO, for instance, estimated internal contamination levels of the Japanese population used in its Fukushima reports based on the percentage over-limit that food monitoring detected, without acknowledging that over-limit items were being banned and effectively kept off the market. The official agencies in Japan that are responsible for the monitoring should demonstrate that they care about making it easier to find and interpret the tests they have been doing. The information is being collected and made available, and communication has definitely improved, but it needs to be vastly friendlier.

Conscientious and thorough food monitoring will need to be continued for years, and in fact there are many good reasons to expand the testing in prefectures outside of Fukushima. But there is a real risk is that public interest will decrease to the point that the government can find excuses to scale it back instead. And while the Japanese 100Bq/kg limit for cesium in food is the strictest in the world, some insist that it is still too high. This in itself is worthy of a lengthy debate, and while the subject is controversial, just about everyone agrees that less is better.

2.4.2b— Food In General



Graph showing changing rates of detection of above-limit items in Fukushima from 2011 through mid 2012. (Credit: Merz, Shozugawa, Steinhauser -Nature Magazine, 2015,)

Nationwide results, all food catgories:

FY2011: 137,037 items tested:
1,204 over 500 Bq/Kg (0.88%)

FY2012: 278,275 items tested:
2,372 over 100 Bq/Kg (0.85%)

FY2013: 326,582 items tested:
975 over 100 Bq/Kg (0.29%)

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608 over 100 Bq/Kg (1.5%)

FY2014: 35,461 items tested:
242 over 100 Bq/Kg (0.9%)

Source: Ministry of Health, Labor, and Welfare (MHLW) food test results, with breakdowns by prefecture and food type:

http://www.mhlw.go.jp/english/topics/2011eq/index_food_radioactive.html

We regularly hear reports of contaminated items being found, and many people may assume that these reports represent a significant proportion of everything that's being tested, and that a lot of contaminated food is in circulation. But examining the MHLW database, which is open for download, and summaries released in English, shows that this is not the case. This data provides results for food items tested before being approved for sale. These include agricultural products, livestock products, fishery products, milk, wild game, drinking water, and others. Using this data it is possible to get an idea of how much food has been over-limit, and to judge the effectiveness of the steps taken to reduce it. Please note that until April 2012 the Japanese limit for cesium in most food items was 500 Bq/kg, in line with standards in most other countries, but a lower limit of 100 Bq/kg went into effect after April 2012. This data is reinforced by surveys and actual tests of what people are eating, and by internal contamination screening results, as well as independent food test results (described below).

When looking at overall results, it's important to be aware of the proportions represented by various categories of food being tested, because the picture changes somewhat depending on what's being looked at. Most people are primarily interested in knowing about agricultural products like fruits and vegetables from Fukushima, however, and fish in general. But a large proportion of the tests so far have been for livestock products, which have had a very low detection rate (less than 1%). During FY2011, the first year of testing, more than 90,000 of the samples were for beef; this appears to be an outsized response to the contaminated rice straw used as feed in some locations that year. During FY2012, more than 50% of the samples still seem to have been for beef, with over 125,000 beef samples measured through Dec., 2012. A large proportion is still for beef, but we think reductions in the number of these samples accounts for about half of the decrease in overall numbers tested between 2013 and 2014.

One persistent concern is that even though only about 1% of food produced in Fukushima is presently over-limit, and is being effectively kept off the market, it may be possible for some people to eat a lot of highly contaminated food nevertheless. People growing or gathering food for their own consumption are not required to have it tested, but are encouraged to do so. Not surprisingly, the highest levels of internal cesium contamination among Fukushima residents found so far has been in people who ignored this advice and regularly ate untested wild or homegrown food, particularly wild mushrooms and berries, or game like wild boar and deer, which are known to present a particularly high risk of contamination. Some of these items are circulated among friends and relatives, but are not approved for sale. We should expect exposures from untested food to continue to happen for many years to come, since the highly contaminated wild foods are found in forests which, as described in the "Environment" section above, are not likely to undergo any kind of effective decontamination, and human nature shows that some temptations are irresistible even when negative consequences are known. At present, these cases form the "long tail" of the distribution, a persistent but fortunately quite small percentage of the overall pattern of consumption of radioactive food.

Similarly, while food intervention measures were instituted fairly quickly in March 2011, they were not immediately effective, and many people undoubtedly ate some contaminated food during the early period, which contributed to their initial doses. The fact that it was still winter in Fukushima, and the ground was frozen and often snow-covered, means that there were almost no vegetables in the ground, which was very fortunate. This is not necessarily the case in prefectures further south which also received fallout.

Fukushima Pref has a page in English where items can be searched by type and date:

Fukushima Prefecture food monitoring info

http://www.new-fukushima.jp/monitoring/en/

This is a useful interactive map of how food contamination levels have changed in Fukushima, produced by Tokyo Polytechnic University:

Radiation and Food Map in Japan
http://foodradiation.org/map/index_e.html

Prof. Haruhiko Okumura of Mie University has been maintaining a searchable archive of the MHLW database (in Japanese):

Mie Unv. searchable food radiation database
http://oku.edu.mie-u.ac.jp/food/

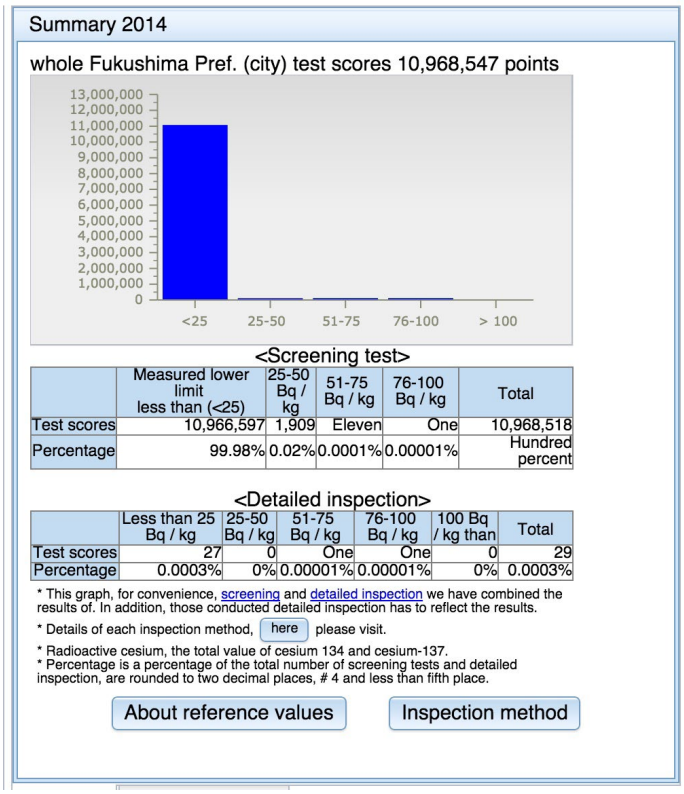
MHLW/National Institute of Public Health searchable food radiation database
http://www.radioactivity-db.info

Recent articles and papers about changing levels of radioactivity detected in food in Fukushima:

Fukushima data show rise and fall in food radioactivity, Nature, 27 February 2015
http://www.nature.com/news/fukushima-data-show-rise-and-fall-in-food-radioactivity-1.17016?WT.mc_id=TWT_NatureNews

Analysis of Japanese Radionuclide Monitoring Data of Food Before and After the Fukushima Nuclear Accident; Merz, Shozugawa, Steinhauser, 2015
http://pubs.acs.org/doi/full/10.1021/es5057648#notes-2

2.4.2c— Rice



Results of screening tests for Fukushima rice, 2014. (Credit: Fukushima prefecture)

As mentioned above, remediation of rice fields in Fukushima has been an extremely high priority, and the central government, prefectural and local governments, local farmers' cooperatives, and individual farmers have all devoted tremendous time and resources into learning how to grow uncontaminated rice and putting it into practice on a large scale. The results have exceeded expectations.

Detailed information on the *"Zenbukuro kensa"* (all-bag testing) rice testing results can be found here:

Fukushima Prefecture food test information, rice:
https://fukumegu.org/ok/kome/

This excellent recent paper describes the testing process for rice in detail:

Inspections of radiocesium concentration levels in rice from Fukushima Prefecture after the Fukushima Daiichi Nuclear Power Plant accident, Nihei et al, 2015

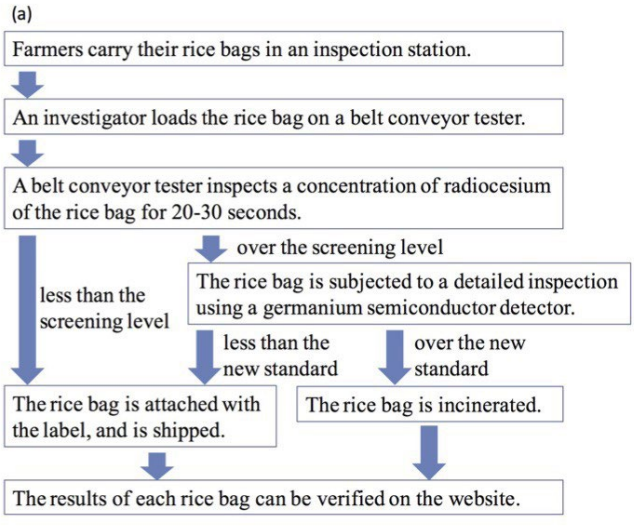
http://www.nature.com/srep/2015/150303/srep08653/pdf/srep08653.pdf

Barcode for access to testing data on bag of rice from Fukushima (credit: FukushimaPref.)

Rice grown in Fukushima is labeled with a barcode, which consumers can use with a smartphone to call up data about the bag, including where it was grown, when harvested, and its measured cesium content (if any). Similar barcodes are gradually being introduced for other agricultural products.

Fukushima Pref: Testing of All Rice Grown in Fukushima Prefecture (JA Aizu Iide) Oct 2013

https://www.pref.fukushima.lg.jp/site/voice-en/jetreport201310-cir04-en.html



Flowchart of rice testing process(Credit: Nihei et al, 2015)

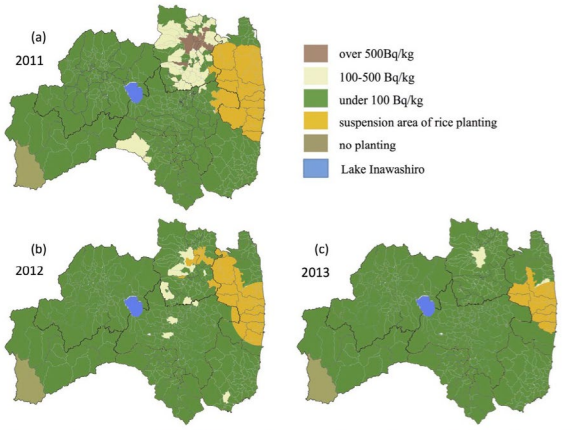
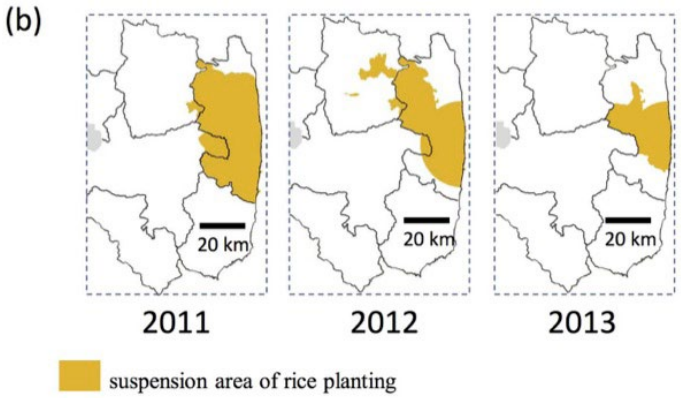


Figure 7 | Chart sorting the former municipalities (classifications as of February 1, 1950), including 374 sectors of the Prefecture, by color according to their maximum values of radiocesium concentration levels in rice, measured by the preliminary survey, the main inspection, or the emergency survey in 2011 (a) and by detailed inspection using a germanium semiconductor detector employed after the screening of the inspection of all rice in 2012 (b) and 2013 (c). Blue area; Lake Inawashiro. The blank paper map of Japan was provided by Fukushima prefecture, which was made from the data source of National Land numerical information (XML format) in Geospatial Information Authority of Japan website (http://nlftp.mlit.go.jp/ksj/jpgis/datalist/KsjTmplt-N03.html). After the blank paper map was scanned, the data was modified by using GIMP2.8 (http://www.gimp.org).

Maps showing radiation levels deteted in rice, etc., during initial surveys in 2011 (Credit: Nihei et al, 2015)



Map showing areas where rice growing was prohibited, 2011–2013. (Credit: Nihei et al, 2015)

As described in the paper by Nihei et al above, in 2011 preliminary surveys and inspections were done of rice fields in all municipalities in Fukushima, which determined that 0.8% of all areas in Fukushima Prefecture had rice contamination levels higher than 100 Bq/kg. Based on this, no-planting areas were determined.

–Rice from most areas of Fukushima is allowed to be sold if it passes the *"zen-bukuro"* (whole bag) screening, with detected levels of Cs below 100 Bq/kg.

–Several areas, generally within the boundaries of the former and current evacuation zones, allow experimental planting only: rice is grown in a few selected locations, tested, and disposed of. This includes the parts of Minamisoma that lie within 20km of Daiichi, and the still-restricted western slice. Also the entire towns of Namie, Futaba, Okuma, Tomioka, and Katsurao.

–Other areas, including the rest of Minamisoma, as well as Iitate, Naraha, and parts of Kawauchi and Kawamata, are currently designated as "prepare to resume planting" areas. Rice can be grown, farmers can get experience with remediation and soil additives (potassium, zeolite, etc), and the rice is tested under the *"zen-bukuro"* screening system. Rice that is under the 100Bq/kg limit can be sold at local events, but not on the open market. Rice from the "experimental planting only" areas can't be sold at all.

Through this testing process, more rice fields have returned to full production each year.

MAFF map of changes in rice planting areas for 2015 (in Japanese):

http://www.maff.go.jp/j/press/seisan/kokumotu/pdf/150227-03.pdf

—"Tobichitta jikken"

An unusual problem from 2013-2014 highlights the continuing vulnerability of agricultural fields to wind-blown and other contamination. For the 2013 Fukushima rice crop, as mentioned above, only 28 of almost 11 million bags were found to be above 100 Bq/kg. 27 of these came from fields in Old Ota-Village in Minamisoma, and ranged from 110 to 180 Bq/kg. Rice from this town also had a much higher proportion of rice above 50Bq/kg (it has generally been less than 0.1%). Farmers and officials were extremely puzzled that this one group of fields was higher than others which had been treated in the same way, and MAFF conducted a series of tests of soil, water, etc.. They released a report in Jan. 2014, and an update in March 2014. They found some differences in soil which could have increased Cs uptake, but not enough to account for what the screening showed. They were able to rule out any sudden increase in water contamination or similar factors, and suspected an "external factor" was the cause.

Govt reports (in Japanese):
Fukushima Pref/ MAFF.: Factors leading to a high concentration of radioactive cesium in rice and their countermeasures, Jan. 2013

http://www.pref.fukushima.lg.jp/download/1/youinkaiseki-kome130124.pdf

Fukushima Pref./MAFF: Factors leading to a high concentration of radioactive cesium in rice and their countermeasures, Ver. 2, Jan. 2013

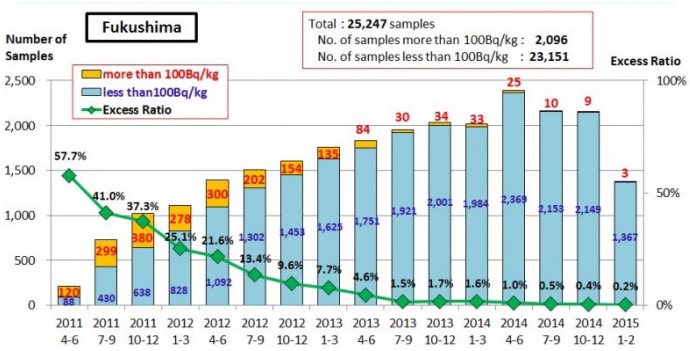
http://www.maff.go.jp/j/kanbo/joho/saigai/pdf/youin_kome2.pdf

Meanwhile on Feb 14, 2014, an information session was held in Minamisoma, at which officials suggested that based on an analysis of maps, wind direction, and timing, airborne contamination from Daiichi in August 2013 was the cause. At that time work was being at Unit 3 at Daiichi, in which a large girder was lifted from the roof, releasing highly contaminated dust which was blown by fairly strong winds. Because of the timing, the work being done at Unit 3 at the time, the wind speed and direction, the areas affected, and measured increases in air radioactivity in the affected areas at the time, dust from Unit 3 is the best explanation so far.

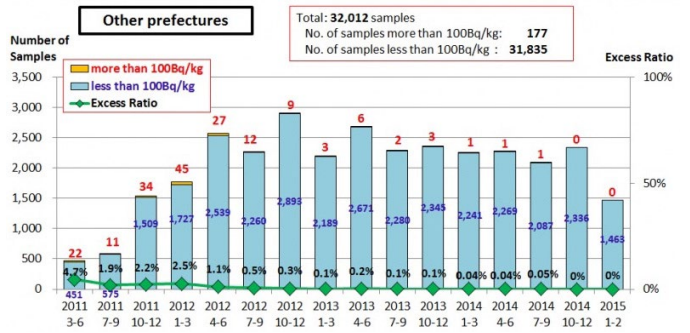
On the one hand it seems implausible that this relatively small amount of dust could be carried so far, but again, this remains the best explanation. It's possible that in each of these fields, a relatively small percentage of rice plants were directly affected, the dose rate of the dust being high enough that when the rice was processed, rice from entire fields ended up with 110-180 Bq/kg.

All of which should be a cautionary lesson not to assume that farm field contamination problems, once solved, will stay solved.

2.4.2d— Fish



Graphs of official seafood testing results in Fukushima showing change over time through Feb. 2015 .(Credit: MAFF)



Graph of official seafood testing results in prefectures other than Fukushima, showing change over time through Feb. 2015 .(Credit: MAFF)

A lot of testing focuses on fish, or more specifically, on "fisheries products," which includes shellfish, octopus and squid, as well as seaweed and a few other items. These items are included in the MHLW testing, but the MAFF conducts its own tests and maintains a separate database as well, through its Japan Fisheries Agency (JFA) branch.

This Fisheries Agency report from May 2014 provides a detailed explanation of the policies, methods, and results of seafood monitoring:

Report on the Monitoring of Radionuclides in Fishery Products (March 2011 – March 2014)

http://www.jfa.maff.go.jp/e/inspection/pdf/fullreport.pdf

Downloadable MAFF fisheries test reports (Japanese only):

http://www.jfa.maff.go.jp/j/housyanou/kekka.html

Page with links to reports in English:

http://www.jfa.maff.go.jp/e/inspection/index.html

Results of tests for strontium, June 2011- Nov 2014 (relatively little testing for strontium has been done):

http://www.jfa.maff.go.jp/e/inspection/pdf/141127_strontium.pdf

Fairly informative Q&A about seafood monitoring (English):

http://www.jfa.maff.go.jp/e/q_a/index.html

In addition, monitoring results from tests conducted by prefectural governments, as well as by a number of fisheries associations, are published online. List and links at the bottom of this web page:

Fisheries monitoring results from tests conducted by prefectural governments,etc..

http://www.jfa.maff.go.jp/e/inspection/index.html

A typical individual MAFF report, in this case covering from April, 2014- Feb 2015

http://www.jfa.maff.go.jp/e/inspection/pdf/e150227.pdf

The same report in .xls format.

http://www.jfa.maff.go.jp/e/inspection/other/e150227.xls

It's a very detailed report, with over a thousand individual test entries, giving results, testing parameters, dates, the location the fish were caught, etc.. The data can be downloaded in both pdf and excel formats, and all the older data is available. These reports are nevertheless unwieldy, and it is difficult to extract trends regarding specific locations, or kinds of fish. In October 2012, a US-based researcher Ken Buesseler at the Woods Hole Oceanographic Institute released a study that used the same MAFF database, and analyzed it to show what kinds of fish were decreasing in contamination and where, and what kinds were not:

WHOI press release: Fishing for Answers off Fukushima, October 25, 2012

http://www.whoi.edu/page.do?pid=7545&tid=3622&cid=153749

Science Magazine: Fishing for Answers off Fukushima (Buesseler, 2012)

http://www.sciencemag.org/content/338/6106/480.summary

A more recent paper provides another excellent overview of changes in radionuclide levels in the ocean as well as in fish since 2011:

Fukushima radionuclides in the NW Pacific, and assessment of doses for Japanese and world population from ingestion of seafood, Povinec, Hirose, 2015

http://www.nature.com/srep/2015/150312/srep09016/pdf/srep09016.pdf

The Ministry of Agriculture, Forestry, and Fisheries should be preparing and providing these kinds of analyses and visualizations itself, to help citizens evaluate the risks.

2.4.2e— Independent Testing Overview

Those who criticize the overall food monitoring system call it "spot checking," and insist that it is too porous, and must be allowing a lot of contaminated food onto the market. But in fact results frequently released by the many independent, citizen-run food testing labs that have sprung up, such as CRMS (Citizens' Radioactivity Measuring Station), as well as by COOP Fukushima, which tests food it sells itself and conducts regular "duplicate portion" surveys of members' households, and the *Minna no Data* project, which provides a searchable online database of food test

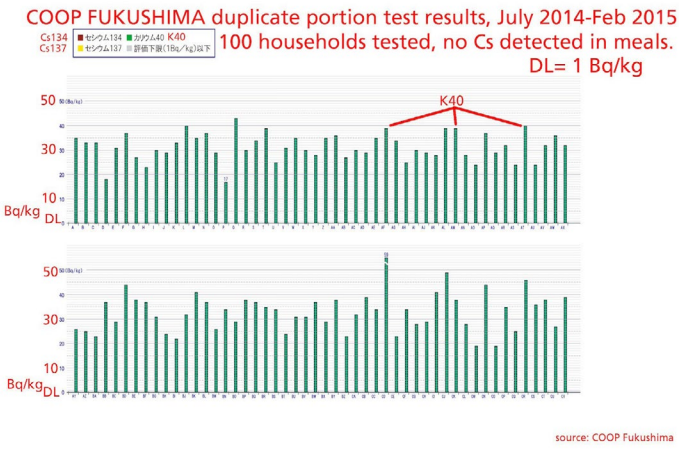
results from over 20 citizens-run testing labs, almost always reinforce the government's claims (see links and summaries below). A higher percentage of contaminated items is often found by independent labs, but the labs themselves acknowledge that people usually bring food they're particularly worried about to be tested, like wild or homegrown items or other "grey market" products which have actually not been approved for sale and which are not representative of what it actually found in stores. Above-limit items can be found, but even independent watchdog groups rarely report finding them on supermarket shelves, and their reports tend to focus instead on instances of any contamination at all that has been detected. The independent labs play an important role in helping keep pressure on the government to be accurate and thorough in its monitoring, and for testing things the government doesn't.

– COOP Fukushima:

In order to see how official food testing compares to independent tests, it's worth looking at COOP Fukushima's independent "duplicate portion" studies from late 2011 to early 2015. These studies sample only a few hundred families in Fukushima, but they're very carefully done. The duplicate portion studies tend to show a bit higher intake than the government's "market basket" studies do, most likely because some families who participate in the COOP study regularly consume many home-grown products that have not been tested.

Test description (in Japanese):

http://www.fukushima.coop/info/important/detail.php?d=ede136d917fd424cf82c581c332b55d04fc05caf-http://www.fukushima.coop/kagezen/2011.html



(Credit: Coop Fukushima; annotations by SAFECAST)

Results for July 2014 – Feb 2015 (in Japanese):

http://www.fukushima.coop/kagezen/2014.html

Fukushima Minpo: Home-cooked meals in Fukushima found to include no detectable radioactive cesium, March 7, 2015

http://www.fukushimaminponews.com/news.html?id=480

Meals of 600 families have been tested since Nov. 2011. Each participating family prepared six meals over a two-day period for testing. Almost all of the households in the survey eat locally-produced food and drink tap water.

Results summary:

Test A: 100 households were tested between Nov. 2011-April 2012; Cs detected in meals of 10 families (10%).

Test B: 100 households were tested between June-Sept, 2012; Cs detected in in meals of 1 family (1%).

Test C: 100 households were tested between Dec 2012 and Feb 2013; Cs detected in meals of 7 families (7%)

Test D: 100 households were tested between July 2013 and Oct 2013; Cs detected in meals of 2 families (2%)

Test E: 100 households were tested between Nov 2013 and Feb 2014; Cs detected in meals of 4 families (4%)

Test F: 100 households were tested between July 2014 and Feb 2015; Cs detected in meals of none (0%)

In each set of tests, 90% or more of the households ate food from Fukushima Pref., though the percentage varies, as does the proportion that each purchased at a supermarket vs home-grown.

In most cases, when cesium was detected in the COOP survey samples, it was barely at the detection level. The highest measured levels of Cs 134 and 137 combined in the food consumed by the participating households are:

Test A: 11.7Bq/kg /day (one family, which ate a lot of home-grown, unchecked food)

Test B: 3.2Bq/kg /day

Test C: 3.5Bq/kg/day

Test D: 1.6 Bq/day

Test E: 2.6 Bq/day

NOTE: It's worth comparing these results with cesium intake levels during the atomic bomb testing period. For instance, according to gov't data, in 1963, every household in the country was consuming an estimated 4.4Bq per person per day nationwide. Similar intake levels continued for several years.

– Market basket tests

The government has conducting several "market basket" tests, though the most recent data we can find is from 2012. It covered 18 prefectures, including Fukushima. The samples were all commercially available food, from 13 food groups, with a focus on local fresh products. Over 200 food varieties were tested. The reports themselves are in Japanese, but a paper by Tsutsumi, et al, based on the 2011 MHLW market basket study is available. It includes an English abstract and many useful graphs, including fairly complete breakdowns in Bq/kg by food type and area studied:

Estimation of the Committed Effective Dose of Radioactive Cesium and Potassium by the Market Basket Method, Tsutsumi et al, 2012

https://www.jstage.jst.go.jp/article/shokueishi/54/1/54_7/_pdf

Mar-Aug 2011 MHLW market basket study (in japanese):

http://www.mhlw.go.jp/shinsai_jouhou/dl/hibakusenryousuikei_02.pdf

Sept-Nov 2011 MHLW market basket study (in Japanese):
http://www.mhlw.go.jp/stf/shingi/2r985200001yw1j-att/2r9852000001ywe9.pdf

Feb-Mar 2012 MHLW market basket study (in Japanese):
http://www.mhlw.go.jp/shinsai_jouhou/dl/20130417-4.pdf

Sept-Oct 2012 MHLW market basket study (in Japanese):
http://www.mhlw.go.jp/stf/houdou/2r98520000034z6e-att/2r98520000034zam.pdf

Results summary:

–The annual radiation dose that would be received from eating food for an entire year that had the radioactive cesium levels found in food tested from September to October, 2012 (15 areas), is from 0.0009 ~ 0.0057 mSv/year. This dose is 0.6% or less of the 1mSv/year annual limit .

–The annual dose from K-40 is 0.14~0.22mSv/year, and is unaffected by the NPP accident.

–Highest doses were in Miyagi, followed by Iwate, Fukushima, Ibaraki, Tochigi

–Changes in dose from 2011-2012:

Sept- Nov 2011: Cs = 0.0024-0.019 mSv/y

Feb-Mar 2012: Cs = 0.0009-0.0094 mSv/y

Sept-Oct 2012: Cs = 0.0009 ~ 0.0057 mSv/y

Central Fukushima only:

Sept- Nov 2011: Cs = 0.019 mSv/y

Feb-Mar 2012: Cs = 0.0066 mSv/y

Sept-Oct 2012: Cs = 0.0038 mSv/y

This indicates that the dose has been decreasing over time.

– Fukushima Pref. duplicate portion tests

Fukushima Pref. has also been conducting duplicate portion tests, but as has often been the case with prefectural data, their results have not been reported as informatively as they should be, though the 2013 report is slightly improved over the 2012 report. No 2014 report is available.

Report, Sept. 24, 2012 (link dead)
http://wwwcms.pref.fukushima.jp/download/1/nitijyousyoku0924.pdf

Report, Feb. 20, 2013 (link dead)
http://wwwcms.pref.fukushima.jp/download/1/nitijyousyoku2013-0220.pdf

Summary of Feb. 2013 report:

This was the second duplicate portion survey done by Fukushima Pref.. 77 Fukushima residents participated from Sept-Nov 2012. The survey included households from 7 regions in Fukushima prefecture, with participants ranging in age from 0 to 70 years old. Each person saved an extra portion of all meals, including snacks and beverages, that he/she consumed for one day, and sent it to the testing center.

Cesium was detected in 56 samples, or 73%. The breakdown is as follows:

21 samples ND (not detected) at a detection limit of 0.054-0.029 Bq/kg

53 detected, less than 1 Bq/kg

2 detected, between 1-2 Bq/Kg

1 detected, more than 2 Bq/kg. (This person's food showed 171 Bq/kg. This family habitually ate wild foods it gathered, such as mushrooms, as well as food it grew itself.)

– Minna no Data

Minna no data ("Everyone's data") is a joint searchable online database which combines food radiation measurements from approximately 20 citizens' run labs in several prefectures. The site was launched in Sept. 2014, and new features gradually added. Both English and Japanese language are available:

***Minna no Data* site:**
http://en.minnanods.net/MDS/

Tested food items can be searched by prefecture, by food variety, by date tested, and a few other parameters. The database currently contains slightly over 10,000 items from all over the country. Of the 2337 tested samples from Fukushima, 57 had cesium detected, 8 were over 100 Bq/kg (0.34%). All others were ND. The over-limit rate for these samples is actually much lower than for official testing.

For Miyagi Pref., 45 of 1003 samples were over 100 Bq/kg (4.4%); almost all were mushrooms, and several of wild boar. This seems to reflect the fact that locals are concerned about these items and so the database includes many of them; also that many are in fact contaminated.

– CRMS

CRMS (Citizens Radioactivity Measuring Station) operates several food monitoring labs, in Nihonmatsu, Sukagawa, Tamura, Koriyama, and Tokyo (In late 2013, their former lab in Fukushima City was split off.)

CRMS Main page:
http://www.crms-jpn.com/art/148.html

CRMS English page:
http://en.crms-jpn.org/

Food test results page (in Japanese, but very readable with auto-translate):
http://www.crms-jpn.org/mrdatafoodcat/

http://www.crms-jpn.com/mrdatafoodcat/food_vegetables.html

Summary of results from 2013 (English press release; no more recent summary appears to be available):
http://en.crms-jpn.org/art/226.html

Analysis of results (Japanese)
http://www.crms-jpn.org/doc/別紙_放射能汚染測定データ分析結果について.pdf

Brief take away of CRMS food test findings:

Of 6886 items tested until 2013 from all over the country, 452 (6.56%) were above 100Bq/kg. For Fukushima alone, 6126 items tested, 427 (6.97%) were above 100Bq/kg.

Higher percentages are reported for lower levels of contamination, such as 13.61% at 50Bq/kg for food from Fukushima. These samples include many homegrown items, and items which were not approved for sale and for which advisories have been in place since 2011, such as wild mushrooms, wild boar, etc.. This dataset may well represent what the contamination levels of the food supply would be like if no monitoring was being done.

– Greenpeace:
Greenpeace has conducted several food monitoring surveys, and results (in Japanese) can be found here:

Greenpeace Japan Monitoring:
http://www.greenpeace.org/japan/monitoring/

Their most recent survey including food measurement data is from June 2013. These surveys are usually not very large, a couple of dozen items each time. Some recent ones include:

– Fish samples caught at sea, which appears to have been done in collaboration with local fishermen. A recent report from June, 2013, has several samples from Tomioka, 10 km south of the plant, as well as from Chiba and other locations, 25 samples in all. The highest level found in this group was in a sea snail collected off Tomioka, at 90Bq/kg. Only 8 of the samples had detectable cesium.:

Greenpeace 20th Japan Monitoring report, June 2013
http://www.greenpeace.org/japan/monitoring/20th/

– Samples bought in supermarkets. The most recent test at the time of writing is from April, 2013, and includes 30 samples of seafood products which originated in Hokkaido, Iwate, Miyagi, Chiba, Mie, Wakayama, Hyogo, Tottori, Kagoshima, Oita, and Nagasaki, and had been purchased in supermarkets in Tokyo, Kanagawa, Osaka and Nara. Only two of the samples in this group had detectable cesium; the highest was a Pacific cod from Iwate, which had 7.4 Bq/kg:

Greenpeace Japan supermarket test results April, 2013
http://www.greenpeace.org/japan/fss13/

A handful of early Greenpeace food test reports in English from 2011 can be downloaded from this page. At the time these were released not much official information was available, and they helped fill the gap:

Greenpeace food test reports in English, 2011
http://www.greenpeace.org/international/en/campaigns/nuclear/safety/accidents/Fukushima-nuclear-disaster/Radiation-field-team/

Direct links to English language reports from 2011 (1):
http://www.greenpeace.org/international/Global/international/publications/nuclear/2011/Report%20SCK%20CEN.pdf

Direct links to English language reports from 2011 (2)
http://www.greenpeace.org/international/Global/international/publications/nuclear/2011/RAP110522-GPJ-01.pdf

(Thanks to Antonio Portela for his assistance in compiling this data. Some previously appeared on the FCCJ Number 1 Shimbun website)

2.5- HEALTH

The concern about health damage from radiation exposure, and particularly the vulnerability of children, has made it the single most contentious issue surrounding the Fukushima disaster. Health concerns are the reason people were evacuated, and prompted many families to mistrust official assurances and move away on their own. The problem is exacerbated by the fact that the most likely radiation-related diseases, such as cancer and leukemia, will not appear for years after the exposures, and will only be detected by large-scale, long-term monitoring. The government quickly got such programs up and running, and the results so far give cause for cautions optimism, but it is too early to tell, and inadequate transparency and poor communication have left many citizens suspicious.

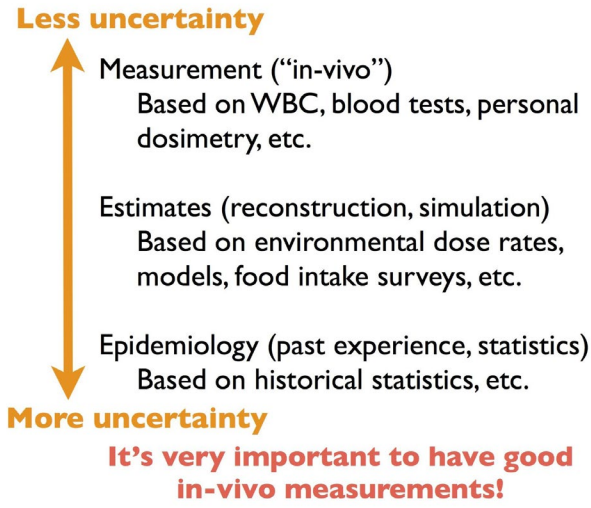
—Introduction

In the wake of a nuclear disaster health concerns are paramount. The concerns include thyroid cancer, leukemia, other cancers, birth defects, other diseases, and the possibility of DNA mutations which might affect future generations. Some of these concerns may be well-founded, some not, but regardless they weigh heavily on families and individuals who must make quick decisions about whether or not to evacuate, whether or not to let their children play outside, whether or not to eat local food or drink local water, whether to risk getting pregnant. Uncertainties abound, and this stressful situation can be compounded by actions by government and other authorities which destroy trust.

We think affected populations have had many legitimate grievances in this regard after the Fukushima disaster. It would seem impossible for people not to question whether or not the government was doing everything could to ensure their health and safety, to ask whether or not justice was being done, in terms of compensation and accountability, and to question how people could really be compensated for such massive damage to their lives anyway.

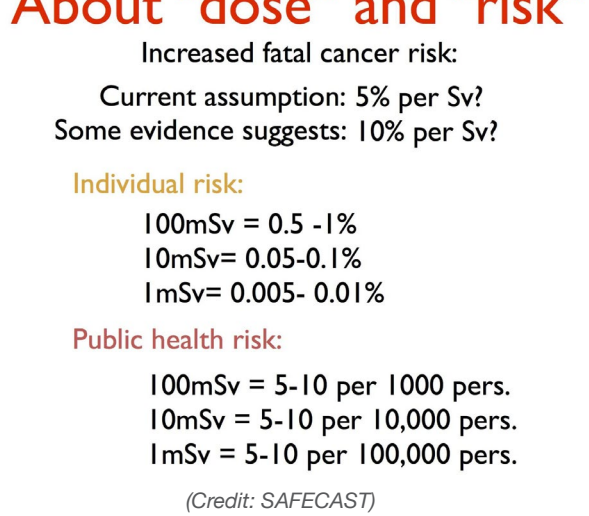
As far as health risks are concerned, they usually are accompanied by a great deal of uncertainty. For most health risks it is almost always impossible to say conclusively how many people will get sick in any particular situation, and this is also true of risks from radiation. In addition, the vehemence of the arguments about radiation and health seem to make nearly paralyzing doubt unavoidable for people whose families have been exposed.

In any potential health crisis, risk estimates are almost always based on incomplete information. But even when good data is available we're usually left with no more than a "range of probability" that any percentage of the population will contract a disease. In fact, in our current situation, the uncertainty, which is closely linked to how good the underlying information is, is rarely less than a factor of 2, i.e. +/- 2x, while in many cases it's an order of magnitude or more, i.e. +/-10x. This is actually normal, but humans are poorly equipped psychologically to deal with this kind of uncertainty.



(Credit: SAFECAST)

For most radiation-related illnesses, the risk is considered to be proportionally related to the dose of radiation received. The system for estimating doses is extremely complex, and there have been good arguments that it should be replaced with something simpler, particularly when it comes to communicating with the public. But one fundamental principle which should be kept in mind is that dose estimates based on actual measurements of radiation in or on the body (in-vivo measurements) are inherently less uncertain than those which have been based on radiation measured in the surrounding environment (ambient doses); on estimates, not actual measurements, based on records which suggest how much radioactivity the person may have been exposed to or how much radioactive food they may have eaten (dose reconstruction); or on historical statistics that look at correlations between disease incidence and living in a particular place (ecological studies). Estimates based on in-vivo measurements are vastly preferable to and more reliable than reconstructions or simulations. Nevertheless they do not entirely eliminate uncertanty.



(Credit: SAFECAST)

Since late 2011 an increasing amount of in-vivo data for people exposed to Fukushima radiation has been available, collected by both government researchers and by independent groups. But a crucial gap exists in our knowledge of what people were exposed to, particularly for thyroid exposures to I-131, in the first weeks of the accident. This is because not enough in-vivo thyroid dose or other screening was done, and what is available was done under very suboptimal conditions. But when combined with the other available data, it seems like it may be enough to help make acceptable thyroid risk estimates. For chronic exposures through food and from the environment, much more reliable in-vivo data has generally been available since late 2011, but it usually must be used with caveats.

2.5.1—Thyroid disease findings

(Credit: FCCJ; graphic by Andrew Pothecary)

Many people are aware that quite a few children from Fukushima have been diagnosed with thyroid cancer. Because it is also known that many children contracted thyroid cancer after the Chernobyl disaster, it has been easy to come to the conclusion that the Fukushima cancers are radiogenic as well. The fact that very few children in Fukushima received potassium iodide as a protection would seem to lend plausibility to this idea. However, the situation is more complex, and also more uncertain. Nevertheless, it is most likely that the thyroid cancers found so far in Fukushima are not caused by radiation exposure. However, the possibility of some, even quite a few, appearing in future years cannot be ruled out.

In order to understand why this is so, it's important to understand how a large-scale screening program like the one in Fukushima is designed to work.

— The goal is to determine if the *incidence rate* of thyroid cancer is increasing. This requires at least 3 rounds of screening of the same population.

— The first round, called "initial screening," which started in late 2011 and has recently been (almost) completed, should reveal the normal baseline prevalence of the disease, i.e. the percentage of people who normally have it at any given time. An analogy would be a survey to determine how many students in a school normally have asthma in a given year.

— The second round, called "full-scale screening," which began last year and will continue through 2016, should reveal the *normal incidence* of the disease, i.e. how many new cases appear in a given year. By analogy, after finding out how many students have asthma altogether, we check to see how many new cases appeared in the school after the first survey was done.

— The third round, scheduled to begin in 2016, should reveal if the *incidence rate* is increasing. In Chernobyl, the incidence rate was seen to increase rapidly after a few years and continue increasing for over 20 years. This will be the strongest evidence that radiogenic thyroid cancers are appearing. By analogy, if the incidence rate of asthma in the school was seen to climb markedly in subsequent years, we might look for causes or plan medical intervention.

Many diseases such as cancer have latency periods, which is the amount of time that is known to pass between an exposure that causes the disease and its actual appearance. Many cancers have latency periods measured in years, even decades, while since the Chernobyl accident, which showed that the latency period of pediatric thyroid cancer had been greatly overestimated, the expert consensus is that at least 3 to 5 years will elapse between exposure to radioactive iodine (I-131) and the appearance of thyroid cancers in exposed children. Like many medical consensuses, the agreement about thyroid cancer's latency period might change with new evidence. But the initial thyroid screening in Fukushima is widely agreed by specialists to have been done early enough that any cancers that may have been found would not have been due to radiation. We must point out that there are dissenters to this opinion, but very few, and as far as we know no thyroid specialists with strong reputations among them.

Nevertheless the findings have been surprising, and while the government and medical officials who set up the screening program deserve credit for getting it up and running so quickly, they also failed to adequately inform the public about how the overall process was intended to work, or to manage their expectations. Because few large-scale screenings are done anyway for any purpose, it always means entering unknown territory. The planners should have said at the outset, "Don't be surprised if we find a lot of cancers in the first round." As it is, medical professionals we have spoken with who have held counselling sessions for Fukushima residents have said that when they have asked how many people understood that the first round of thyroid screening was intended to establish

the normal baseline prevalence of the disease, not a single person has raised their hands. We consider this a massive and consequential failure of communication. In addition, while results have generally been reported in a timely fashion, they're never as full and as informative as the public, as well as other specialists and researchers, need. All of this has continued to cast a pall of suspicion over the entire process in the eyes of skeptics, and to leave the program's organizers open to accusations of cover-up. We believe the results are sound, as are the committee's basic conclusions. We also want to stress that it will be several years before we will be able to definitively determine if there is an increase in thyroid cancer among the Fukushima population.

—Results and interpretation

Fukushima Prefecture Health Survey thyroid screening program:

Preliminary screening ("first round"- for baseline):

Of 367,687 Fukushima residents who were 18 years and under at the time of the accident and therefore eligible to be screened, 298,577 have been screened so far. Results for 297,046 have been determined.

There have been 109 suspected cancer cases, of which 87 have been confirmed by surgery (rate of 0.03%).

Full-scale screening ("second round"- for normal incidence):

385,000 people are eligible for this round, and 220,000 were targeted to be screened in FY2014; 106,068 were actually screened. Results have been reported for 75,311 individuals so far, about 1/5 of the entire cohort intended to be screened.

A total of 8 suspected cancers were found (1 confirmed, 7 suspected) (rate of 0.01%)

English translations of official reports:

Proceedings of the 18th Prefectural Oversight Committee Meeting for Fukushima Health Management Survey
http://www.fmu.ac.jp/radiationhealth/results/20150212.html

What does this mean?
The results of the first round of screening in Fukushima revealed an unexpectedly high prevalence of thyroid cancer. If these cancers are due to radiation, then the second round of screening should show a similarly high incidence of new cases, and the incidence rate should be seen to increase every year after that. Also, a clear correlation between the incidence rate and the radiation doses received by the children in different parts of Fukushima would be evident. If, on the other hand, the cancers discovered so far are normal and not due to radiation, then the second round will reveal relatively fewer new cases, with no correlation to exposures, and the incidence rate in following years will be similar. The initial results of the second round of screening are consistent with this so far, but it is still too early to tell.

Since 2012 we have been consulting outside experts, including Sir Dillwyn Williams, of Cambridge Univ., a leading endocrinologist who, together with Keith Baverstock and others made a crucial effort to get the thyroid cancer outbreak after Chernobyl acknowledged as being due to radiation. Since that time his continued work on the Chernobyl thyroid cancer issue has been considered essential reading for anyone seriously interested in the subject. A few of his many important texts, including some co-authored with Baverstock, are listed below:

Scientific Correspondence to the Journal Nature from Sept. 1992, announcing that radiogenic thyroid cancer had been found in children in the Chernobyl area; Baverstock, Williams, Demidchik, et al
http://www.ratical.org/radiation/inetSeries/ChernyThyrd.html

The Chernobyl Accident 20 Years On: An Assessment of the Health Consequences and the International Response; Baverstock and Williams, 2006
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1570049/

Twenty years' experience with post-Chernobyl thyroid cancer; Williams, 2008
http://old.ecceterra.org/doc/bp.research.post.chernobyl_20set08.pdf

Radiation carcinogenesis: lessons from Chernobyl; Williams, 2009
http://www.nature.com/onc/journal/v27/n2s/pdf/onc2009349a.pdf

In early 2012, after the first screening results had been reported, Dr. Williams pointed out to us that:

— The observed incidence of any cancer in a population depends on the method used to look for it.

— Any systematic survey will find more cases than the normal system of waiting for the patient or relatives to notice a problem.

—The more sensitive the screening system the larger number of cases will be found.

—This is particularly true for slow growing cancers like thyroid, where it takes a considerable time for the earliest cancer to grow from just a few cells to a detectable lump.

— The chance that the current apparent increase in thyroid tumours is due to radiation exposure is very low.

— The tumors likely pose little health threat.

— High-resolution ultrasound screening is a new technique, and reveals many harmless anomalies.

— Not enough time has passed for radiogenic tumors to appear.

— The doses are uncertain, but appear too low in nearly all areas to cause a detectable increase.

— Unlike at Chernobyl, milk and other contaminated food was stopped soon.

— Unlike at Chernobyl, Japanese children have sufficient iodine in their diet.

— The initial screening study will show the normal baseline prevalence of thyroid tumors.

— It's too early to know for sure how many new cases will arise (incidence), we will have to wait at least 4 years.

(The above was from a personal communication in early 2012, which Dr. Williams gave permission to share, which we did through the SAFECAST mailing list)

The kind of "screening effect" Williams described is well-documented in the health literature, particularly for thyroid cancers:

An Epidemic of Thyroid Cancer? Dr. Gilbert Welch, NYT, Nov 5, 2015
http://www.nytimes.com/2014/11/06/opinion/an-epidemic-of-thyroid-cancer.html

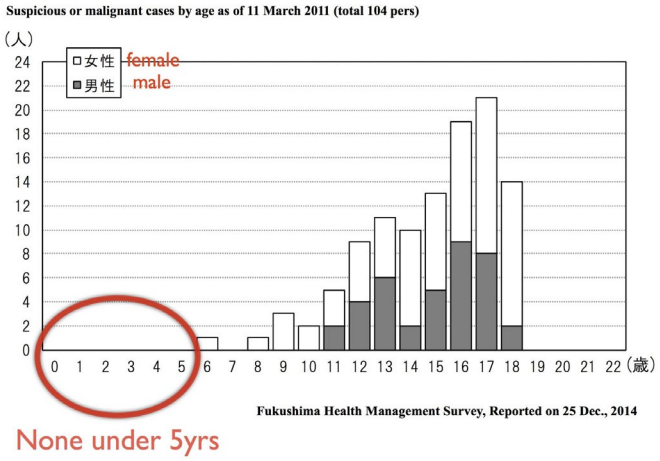
Overdiagnosis and screening for thyroid cancer in Korea; Lee, Shin: The Lancet, Nov. 2014
http://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(14)62242-X.pdf

We shared Dr. Williams' expert opinion online and directly with health professionals and others who were concerned about how to interpret the early findings. As more data became available, similar opinions were expressed by Baverstock, Demidchik, Tronko, Ivanov, Jacob, and other leading experts:

— It's still too soon for the cancers to be caused by radiation.

— If radiation was the cause, then children under 5 would develop the cancers first first, but there have been none in that age group so far.

— There is no clear correlation with dose levels



Graph showing the age at exposure of Fukushima residents diagnosed with thyroid cancer (results as of Dec. 25, 2014). (Credit: Fukushima Pref; annotations by SAFECAST)

Most of these experts have said that it's still too early to know, but we can expect some increase in the future. The consensus on this is strong. And we are now at the 4-year point, where it would not be surprising for some radiation-related thyroid cancers to start appearing.

There are dissenters, however, who believe:

— The rate seems to be increasing 2011-2014.

— Maybe there is a correlation with dose levels.

— Maybe the latency period is actually shorter than 3-5 years.

The evidence presented to support these opinions so far has not been very strong, and based on all of the evidence, there seems to be little likelihood that these dissenters are right. Nevertheless it's important to give them a fair hearing.

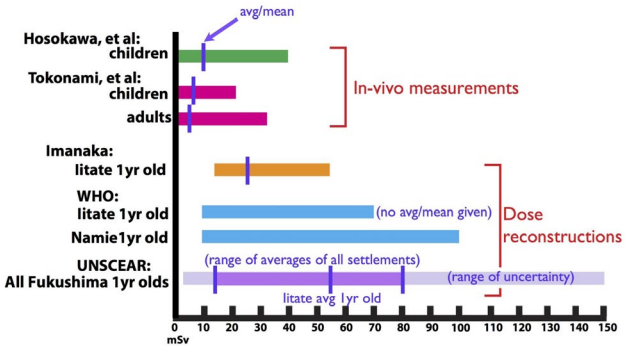
Thyroid Cancer under 19 in Fukushima: the Second Report; Tsuda, 2014
http://ehp.niehs.nih.gov/isee/p1-255/

In late 2012 – mid 2013 a comparison survey was done with 4365 children in Aomori Pref., Yamanashi Pref., and Nagasaki Pref. The ages, 3-18 years, were not perfectly matched to the Fukushima cohort, which was 0-18, and the sex ratio was somewhat different as well. Nevertheless the findings were quite similar to what has been found in Fukushima. Again, the surveys are not perfectly comparable, and the size of the cohort is statistically very small. But it appears to be strong evidence that the Fukushima findings are not unusual.

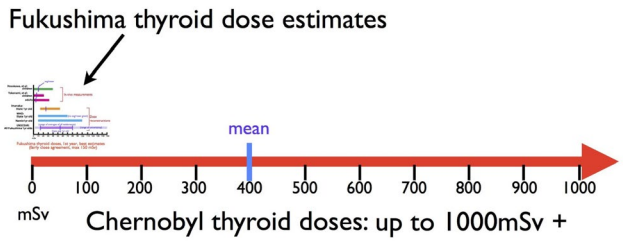
Preliminary report March, 2013; Detailed report, Hayashida, et al, Dec., 2013; Source: Japan Environ. Ministry:
http://www.env.go.jp/press/press.php?serial=16419

Followup report:

Thyroid ultrasound findings in a follow-up survey of children from three Japanese prefectures: Aomori, Yamanashi, and Nagasaki; Hayashida, et al
http://www.nature.com/srep/2015/150312/srep09046/full/srep09046.html



(Credit: SAFECAST)



(But some cancers expected at low dose range)

(Credit: SAFECAST)

Even with the uncertainties about doses, both the available in-vivo measurements and the most thorough reconstructions all indicate that thyroid doses in Fukushima (average/mean about 20- 50 mSv; maximum possibly 150 mSv) were many times lower than at Chernobyl (average 400-450 mSv, maximum well over 1000 mSv).

How much thyroid cancer are we likely to see?
One reasonable estimate of the amount of thyroid cancer we might expect over the next 50 years has been done by so Jacob, et al, 2014:

— The new baseline (normal prevalence) may be about 7x higher than previously believed.

— Based on the estimated percentages, in the next 50 years, with 330,000 people being studied, about 7300 will be diagnosed with thyroid cancer.

— About 300-1000 of these will be new cases (incidence) due to radiation.

— Most of these would not cause health problems if not discovered (i.e. they would be "subclinical").

Ultrasonography survey and thyroid cancer in the Fukushima Prefecture; Jacob, et al, 2014
http://link.springer.com/article/10.1007%2Fs00411-013-0508-3

This study acknowledges many uncertainties, and is not conclusive. But many doctors are worried that the effort to search for radiogenic thyroid cancers is already leading to overdiagnosis and unnecessary operations. As mentioned above, this is a well-documented problem with thyroid cancer screening.

Several leading doctors wrote an article in May 2014 calling attention to this risk and recommending that the thyroid screening program be reconfigured to minimize the risk of unnecessary diagnosis and treatment:

Time to reconsider thyroid cancer screening in Fukushima; Shibuya et al, 2014
http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)60909-0/fulltext?rss%3Dyes

Knowing what we know now, the pros and cons of continuing the screening program appear to be:

Pros:
–Screening reassures the great majority of the population that they do not have a cancer.

–Operating on tumors detected by screening in children may prevent the development of "more difficult to treat" cancers at a later age.

Cons:
–Screening raises the level of concern in the population generally.

–Some, possibly many, of the operations may have been for "technical cancers" which would not have progressed to a dangerous stage.

–Operations carry a risk of complications, even though these are extremely rare in skilled hands.

Will the Fukushima thyroid screening program create more health problems than it solves? Williams suggests that:

"It was appropriate to set up the screening program for those exposed to Fukushima fallout; on balance I believe it will benefit the population as well as providing information that will be very important in the event of another accident. Open discussions with the public to consider all the results and decide on the appropriate future course of action are extremely important." (personal communication)

So far, most experts generally agree with the interpretation of thyroid screening results stated by the gov't, but many people do not believe them. Part of the reason is, as mentioned above, that they have many legitimate grievances, and the purpose of the program, as well as the results, have been very poorly communicated. The best thing to do to improve the credibility of health screening, in our opinion, would be to improve the transparency of the process. The problems are not scientific as much as they are social and communication-based, and rooted in an overly bureaucratic mindset. If we could, as Williams has suggested, offer screening on an individual basis, with an explanation of the risks and benefits, concentrating on the most likely age and dose-exposure groups only, and find a way to involve the communities in the decision making process, then maybe the current public anxiety can be mitigated. However, it looks like entrenched dysfunction now.

— Independent thyroid tests

At least one well-organized independent thyroid screening of a similar age group has been carried out in Fukushima and reported in the scientific press. In many regards it is more comprehensive and informatively reported than the official Fukushima Prefecture program. While the numbers screened, 1137 persons, are too small to either confirm or contradict the official screening, the findings provide a reality check, and can be said to generally support it:

The Thyroid Status of Children and Adolescents in Fukushima Prefecture Examined during 20–30 Months after the Fukushima Nuclear Power Plant Disaster: A Cross-Sectional, Observational Study; Watanobe, et al, Dec. 2014
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0113804

The work was done under the guidance of an independent medical foundation, the **Radiation Countermeasures Research Institute for Earthquake Disaster Recovery Support:**

http://www.fukkousien-zaidan.net/en/index.html

In addition to thyroid ultrasound, thyroid-related blood and urine tests, as well as dose estimates, were done. The authors gave several caveats against regarding their findings as conclusive. They concluded:

"The results obtained revealed no discernible deleterious influences of the emitted radioactivity on the young thyroid. In addition, we did not find any significant relationship between the thyroid ultrasonographic findings and thyroid-relevant biochemical markers….

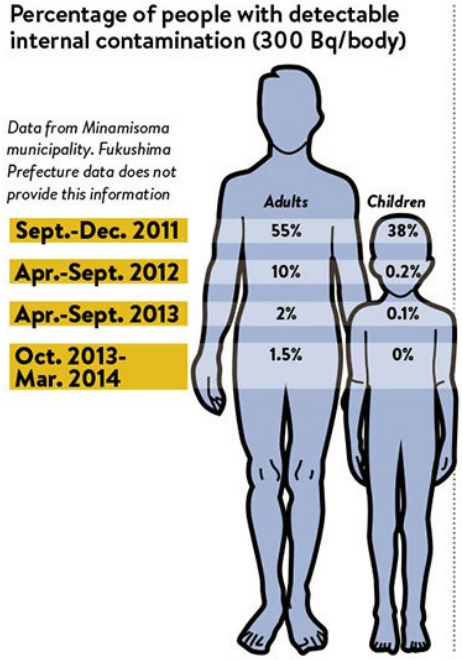
…Whether all the negative results in the current study suggest an insignificant health impact of the FNPP1 accident or reflect the relatively early implementation of thyroid

examinations in the wake of the accident, must await forthcoming studies."

They also pointed out that none of the available data so far *"can decidedly disprove the involvement of the FNPP1 accident in the pathogenesis of at least part, if any, of the above-mentioned 104 cases of confirmed or suspected thyroid cancer [i.e., found in the Fukushima Prefecture screening]."*

(We wish to thank Sir Dillwyn Williams for his advice and input during the drafting of this section)

2.5.2— Internal contamination screening (WBC)



(Credit: FCCJ, graphic by Andrew Pothecary)

The risk of internal contamination from cesium and other radionuclides that have been inhaled or ingested is one of the larger concerns in radiation exposure situations like the Fukushima accident. Because contamination such as cesium can remain in the environment for decades, and end up in food plants and animals, the risk of chronic exposure lasting months or years must be guarded against. As described in the "Food" section above, food intervention and testing is one of the primary tools for guarding against this. Results of internal contamination screening of Fukushima residents with whole body counters (WBC) give cause for cautious optimism than chronic internal exposures have at this point been minimized and can continue to be controlled.

Data from 3 types of programs are available:

–Fukushima Prefecture, whose results very incompletely reported.

–Local governments, such as Minamisoma, Hirata, Soma, etc., which are often the most complete and accurate surveys

–NPOs, such as CRMS and others, which range widely in quality and completeness.

Though their reliability and transparency differ, prefectural, municipal, and independent tests all indicate that internal contamination of Fukushima residents is many times lower than in Chernobyl, with peak levels as much as 10 times lower, and average levels 100 times lower. Food screening results, both official and independent, reinforce this conclusion. Nevertheless, "outliers," that is, individuals with higher contamination levels, are still found. These have invariably been elderly people who continue to eat wild mushrooms and other foods which are highly contaminated, despite having been advised against it.

2.5.2a—Fukushima prefecture WBC program

(Credit: FCCJ, graphic by Andrew Pothecary)

Fukushima Pref. has been conducting its own WBC screening program, and reporting results several times a year. To date this program has screened 242,974 people, and given estimated doses 1mSv or over for 26 of them, meaning that over 99% have had less than 1mSv to date. On the one hand this is good news. But actually, most informed observers consider Fukushima Pref.'s reporting of WBC screening results to be incomplete and uninformative. In particular, while they provide detailed demographic breakdowns according to age sex, location, etc., they do not give a breakdown of the levels of internal contamination actually found, nor of how in many people contamination was undetected (ND).

The fact is that in order to have a one-year dose of 1 mSv, a child 3–7 years old would need to have a cesium intake (Cs-134 plus Cs-137) of approximately14,500 Bq., while an adult would need approximately 48,000 Bq..But the public and experts consider it important to know about much smaller body burdens and doses as well, particularly in order to help evaluate how effective food intervention has been. In particular people have been monitoring how many children have body burdens above 10 Bq/body, because there have been studies (albeit unreliable ones) which suggest that risks increase sharply above this level. Since 2012 several experts have criticized Fukushima Pref. for not providing this body burden breakdown data, in both Bq/body and Bq/kg, and some have helped establish much more helpful and informative WBC programs in various parts of Fukushima.

Comparison of internal contamination data provided

	dose/yr	Bq/body	Bq/kg	repeated tests	identify high risk groups	test food
Municipalities*	✓	✓	✓	✓	✓	✓
Fukushima Pref.	✓	✗	✗	✗	✗	✗

* includes Minamisoma, Hirata, Kawachimura, Miharu and Iwaki

(Credit: FCCJ, graphic by Andrew Pothecary)

In fact, we have heard from reliable sources that the reason Fukushima Pref. does not provide these breakdowns is that their WBC screening protocol does not include weighing

each person, even though this is generally considered an absolute minimum necessity in this kind of screening. There may be workarounds, such as using statistics to estimate body weights, and in fact individuals who have been screened are apparently told their body burdens in Bq/body, so they can calculate the Bq/kg themselves, though this data is not made publicly available. Like the communication failures for the thyroid screening, these problems could have been avoided if at the outset, while planning the programs, the responsible committees had given due consideration to both what the public needs to know and to what would be most useful to food intervention counselors and planners.

Fukushima Pref. WBC screening report, Jan. 2015:
www.pref.fukushima.lg.jp/sec/21045b/wbc-kensa-kekka.html

2.5.2b— WBC Screening programs administered by local governments

In contrast, since 2011, some municipal governments, such as Minamisoma and Hirata, have taken the lead in providing well-planned and well-run WBC screening programs, mostly under the guidance of Dr. Ryugo Hayano and Dr. Masaharu Tsubokura of Tokyo University. Their results are also the most completely and informatively published, and have withstood repeated peer-review. Gradually other local governments, such as Soma, Iwaki, and Kawachimura, have begun to adopt similar standards. These programs are independent of both the prefectural and central governments, and in fact some municipal doctors have complained about the lack of cooperation and information-sharing with prefectural officials.

Among the important features of these municipal surveys are:

— Repeated testing of residents is done to assess changes over time and effectiveness of interventions.

— Families are measured together whenever possible.

— One-to-one counseling is done after tests.

— Development of new technologies for accurately measuring infants and small children, such as the “BabyScan”.

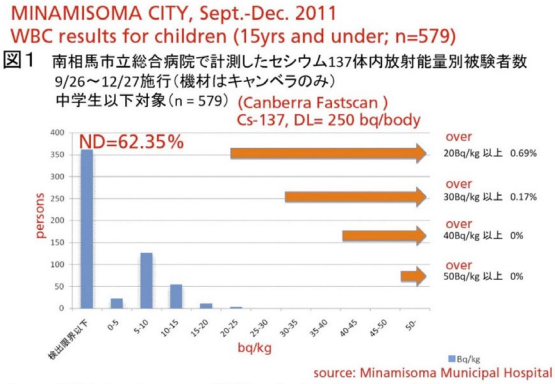
— Clear demographic breakdowns of results by age, gender, etc..

—The teams examine correlations between sources of food, drinking water etc.. and internal contamination levels.

— Excellent graphs and visualizations are provided, as well as internet blogs to explain results.

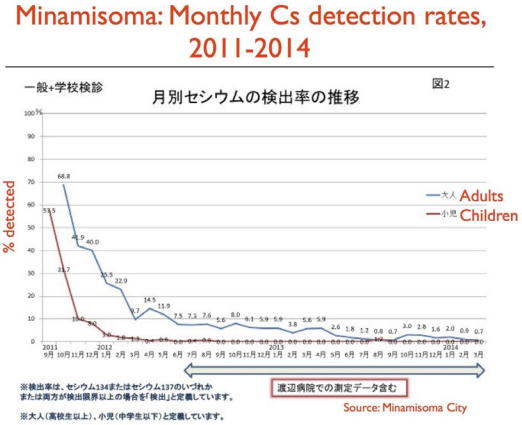
In late 2011, almost 40% of children in Minamisoma had internal contamination above a detection limit of 250 Bq/body.Their initial doses shortly after the accident can only be estimated because WBC devices were not available.

The detection rate declined throughout 2012, and effectively reached zero (though a 20kg child could still have as much as 12 Bq/kg and not be detected). By late 2013, largely due to effective counseling about food sources, the detection rate for adults in Minamisoma also approached zero, and remained effectively zero for children.



In late 2011, almost 40% of children in Minamisoma had internal contamination above a detection limit of 250 Bq/body.Their initial doses shortly after the accident can only be estimated because WBC devices were not available.

(Credit: Minamisoma City; annotated by SAFECAST)



Detection rates for both adults and children in Minamisoma are basically zero at present, but keeping them low will require continual monitoring and counseling.

(Credit: Minamisoma City; annotated by SAFECAST)

Detection rates for both adults and children in Minamisoma are basically zero at present, but keeping them low will require continual monitoring and counseling. The results in Hirata City and in most municipalities with similar screening and counseling programs have been similar. This does not mean these people do not have any cesium in their bodies; if it is an amount below 250 Bq/body, or in the case of children screened using the BabyScan device, 50 Bq/body, then it will not be detected.

WBC data from the City of Minamisoma:
www.city.minamisoma.lg.jp/index.cfm/10,21095,61,344,html

A recent paper describing WBC results from the town of Miharu, where nearly every schoolchild, over 1300 in all, has been scanned more than once, and no internal cesium has been detected since 2012:

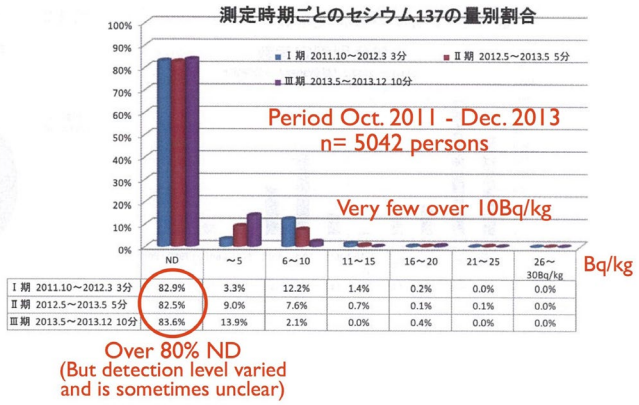
Whole body counter surveys of Miharu-town school children for four consecutive years after the Fukushima NPP accident; Hayano, et al, 2015
http://arxiv.org/abs/1501.02637

So far, good WBC screening data for many Fukushima residents — about 118,000 individual scans, including multiple scans for many people — is available from programs like this, with good datasets dating back to late 2011. The results cannot be considered conclusive, but because they

include people from many parts of the prefecture, and are supported by testing of food and family meals, we think they can be considered very indicative. We believe this testing has reliably shown that the chronic internal doses to these populations are currently less than 0.01 – 0.1mSv/year. While it is believed that even small doses like this carry some health risk, the broader consensus suggests that it very small.

Despite the extremely high quality and conscientiousness of these test procedures and analysis, the doctors and researchers running these programs have occasionally been criticized by anti-nuclear groups and individuals seeking to cast doubt on their findings. We have examined the data and the screening protocols closely, however, and have concluded that such criticism is unfounded. This is, quite simply, the best data available on internal contamination of Fukushima residents, and it is extremely reliable.

2.5.2c—Independent programs



Independent WBC screening report
NPO CRMS Fukushima, Jan. 2014

(Credit: CRMS; annotated by SAFECAST)

In addition to the prefectural and municipal programs, there have been a handful of WBC screening programs run by citizens' groups. These programs generally use less sensitive equipment than the municipal or prefectural programs, and their quality and results have been uneven. Nevertheless, though these groups are specifically motivated to provide an independent check of official data, their findings generally support it.

The longest-running and largest program so far has been run by CRMS in Fukushima City. Data from 2014 tests does not seem to be available yet, however results from 2011-2013 are (please note that this organization underwent a split in late 2013, in which its Fukushima City lab, which had been conducting the WBC screening, split from the rest):

CRMS main site:
http://www.crms-jpn.org/cat/about_wbc.html

CRMS Fukushima:
http://crms-fukushima.blogspot.jp/2014/03/wbc.html

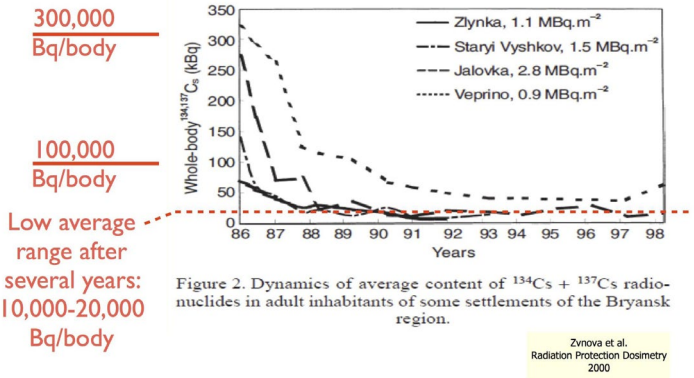
Between Oct. 2011 and Dec. 2013, 5042 persons were scanned. Over 80% were reported to have no internal cesium, at detection limits which varied but were claimed to be as low as 150 Bq/body (We think this is implausibly low given the equipment used, the overall test conditions, and other technical factors, and suggests that in many cases noise has been misidentified as cesium detections through overzealousness). Nevertheless, as in the municipal programs, very few individuals had over 10Bq/kg of internal cesium.

Taken together, the prefectural, municipal, and independent internal contamination screening results indicate that chronic internal contamination in Fukushima is so far being adequately controlled, due to extensive food screening. As has frequently been stated, WBC screening done soon after the first exposures can give a good idea of how big those exposures were, but in fact, while good data from the early weeks of the disaster is available for US military personnel and a few researchers and foreign nationals, very little is available for Fukushima residents until fall of 2011. These tests can help establish a plausible upper limit to the early exposures, but not much more.

2.5.2d— WBC Scams

It was called to our attention last year that a clinic in Tokyo was providing fee-based WBC services, which we were encouraged to check out. Two SAFECAST volunteers went there, and received scans, and were given quite implausibly high test results and a sales pitch. Discussing the system, etc., with the clinician, it quickly became apparent that it was uncalibrated, or as we suspect, miscalibrated to give high readings. The clinic has been using their WBC results to sell extremely expensive treatments, such as sauna mats which they claim eliminate internal cesium through "hormesis," as well as dietary supplements. The information and technical explanations they gave us were also incorrect, and not surprisingly, the clinician attempted to discredit the municipal programs. Other researchers have also visited the clinic, and come to the same conclusion, that its measurements were false, and complaints have apparently been made to local government. Nevertheless, as far as we know, this clinic is still in business, and has scanned and given false results to over 2000 people.

— Comparison to Chernobyl

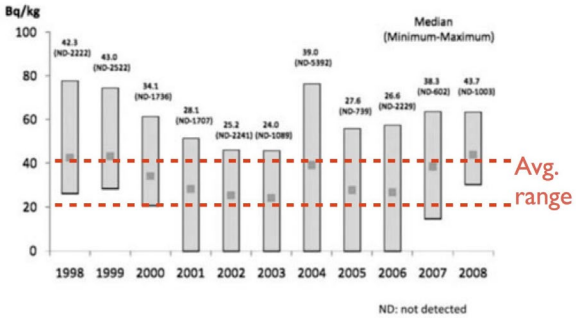


In most areas of Chernobyl, internal contamination was many times higher than what's been found so far in Fukushima.

(Credit: Zvnova, et al, 2000; annotated by SAFECAST)

In most areas of Chernobyl, internal contamination was many times higher than what's been found so far in Fukushima, and has been higher on average even in recent years. During the first several years after the Chernobyl

accident, average internal contamination in many areas were between 100,000 – 300,000 Bq/body, and reached an average in the 1990's of about 10,000 – 20,000 Bq/body, compared to few detections over 250 Bq/body in Fukushima since late 2011. In Chernobyl levels have been between 20-40 Bq/kg as recently as 2008, while so far, in Fukushima, very few people have been found with more than 10 Bq/kg.



Cs-137 detection levels, Bryansk, 1998-2008
Sekitani Radiation Protection Dosimetry (2010), Vol. 141, No. 1, pp. 36–42

Average internal contamination was between 20-40 Bq/kg 10-20 years after Chernobyl accident!

(So far in Fukushima, very few people have been found with more than 10 Bq/kg)

(Credit: Sekitani 2010; annotated by SAFECAST)

It's important to note that internal doses in Chernobyl generally decreased until 1990-91, when the Soviet Union collapsed, and then increased again for several years as food screening was cut back. This is probably the greatest future risk for Fukushima residents in terms of internal contamination, and the reason both conscientious food screening and internal contamination screening will need to be continued for many years.

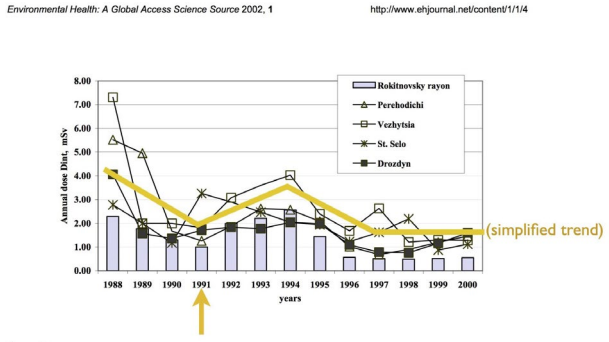


Figure 3
Dynamics of annual effective doses of internal exposure (D_{int}) due to ^{137}Cs ingestion in Rokitnovsky Rayon and selected village, Rivno Oblast, Ukraine by year from Whole Body Count (WBC) data

After Chernobyl, internal doses decreased until 1990-91, then increased again as food screening was cut back. This is probably the greatest future risk for Fukushima residents in terms of internal contamination.

(Credit: Environmental Health; annotated by SAFECAST)

2.5.3—External Exposures

External exposures can be assessed in several ways, and different methods are considered appropriate for different uses. Measures of ambient radiation in the environment, taken with a handheld survey meter or geiger counter, for instance, or from a fixed monitoring post, which provide a measure technically known as "ambient dose equivalent," can be used to arrive at estimates of what people who stay in that environment might be exposed to, and from that, their possible doses ("effective dose"). Converting from ambient doses to people's doses involves a fairly complicated modeling process in which the person is represented by an imaginary sphere. The results are intended to over-estimate doses to people, so as not to underestimate their possible risk, and to provide a ballpark estimate that can be useful for many crucial decisions in times of emergency.

It is much more accurate to use personal dosimetry, which involves small measurement devices worn on the body itself and usually kept on at all times, called "personal dosimeters" (but also colloquially as "glass badges," which is one common type) to estimate doses to individuals (known as "personal dose equivalent"). These devices are calibrated using an actual physical dummy, called a "phantom," which simulates the human torso, and characterizes how the dosimeter itself will respond to known quantities of radiation coming from every direction. The conversion from personal dose equivalent to effective dose is more straightforward, and has less inherent uncertainty than that from ambient doses. In addition, since an individual is wearing the dosimeter constantly it accurately records the radiation levels actually encountered. Nevertheless, this is also considered to be an over-estimation. Natural background radiation is taken into account, and usually subtracted from actual recorded readings, and when results are reported they usually specify whether or not background radiation is included. Personal dosimetry is the preferred method for evaluating actual external exposures, particularly when medical intervention might be necessary.

Ambient doses can also be estimated from known ground contamination, and from that, personal doses can be derived. While this kind of modeling can be quite sophisticated, of the three methods described here it is the most uncertain. If good personal dosimetry is available, it should be used instead. If personal dosimetry isn't available, but ambient doses are, then they should be used. Ground contamination measurements are essential for understanding environmental effects and for planning food interventions, but are considered the least desirable data on which to base individual dose estimates, particularly if better dosimetry is available.

A very detailed and technical explanation of this issue can be found in these texts:

Dose Quantities and Units for Radiation Protection Chapter 2 of Radiation Protection in Nuclear Medicine, 2013; Soren Mattsson and Marcus Soderberg

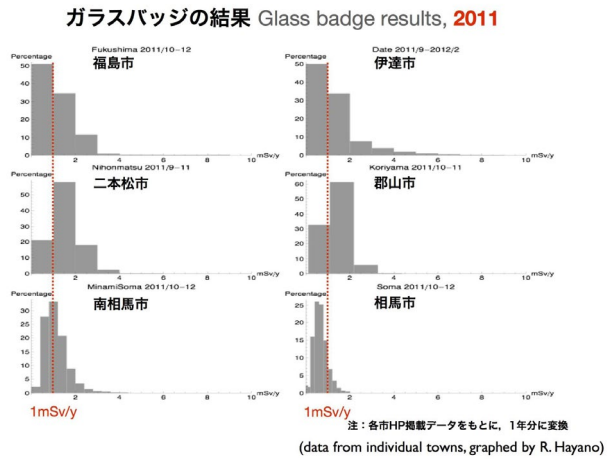
http://link.springer.com/chapter/10.1007%2F978-3-642-31167-3_2

Calibration of radiation protection monitoring instruments IAEA Safety Reports Series No. 16., 2000

http://www-pub.iaea.org/MTCD/publications/PDF/P074_scr.pdf

— Personal dosimetry

Virtually every municipality in Fukushima has done many "glass badge" surveys since 2011, involving large proportions of the population. This is actually unprecedented. When the various current protection guidelines were established, this kind of wide scale availability and deployment of personal dosimetry for the public would have been considered technically and financially unfeasible, and so it is not really anticipated in prior official recommendations. Until now, different cities in Fukushima have used devices from different manufacturers, and there's been no real standardization in how the results are reported. Also, there has been no independent oversight. Nevertheless, results have consistently shown that the doses actually received by people in Fukushima have been much lower than what's been estimated based on ambient dose rates, usually half or less. They suggest that since the programs were started in fall 2011, the majority of external exposures were already under 2 mSv/yr, with a large proportion already under 1 mSv. These findings have met with some public skepticism, however, but no actual manipulation or misrepresentation of the reported data has been demonstrated so far.



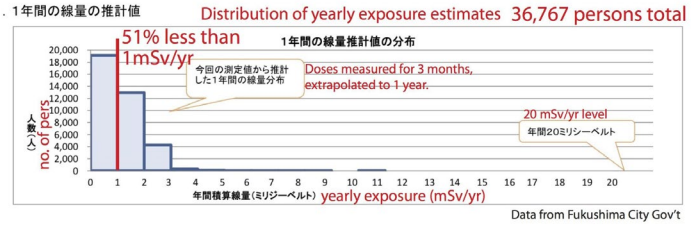
Data from thousands of individuals from many towns in 2011 showed that the majority of external exposures were already under 2 mSv/yr.

(Credit: R. Hayano)

Many dosimeters simply provide a cumulative reading, but recent designs are available which show the levels on an hour-to-hour basis. This is very useful for identifying the locations where the highest exposures are received, so decontamination can be more effectively targeted and residents can be counseled to avoid those locations. Some towns already provide such counseling, and are sharing their experiences with potential counselors in other areas. The government has announced its intention to use doses based on personal dosimetry for more decisions regarding areas to reopen to residence. The idea has met with opposition and suspicion from some quarters, but technically it is sound, for the reasons described above.

Fukushima City's personal dosimetry program results have been regularly reported, and provide a useful illustration of external exposure trends. Fukushima City has a large affected population and can be regarded as fairly representative of the exposures experienced by people living in unevacuated areas; many evacuated areas are populated in the daytime by groups of decontamination workers whose doses are also being recorded, and while a few people are living in these places illegally, the number of these residents is few.

Fukushima City "glass badge" results, 2011



36,767 children and pregnant women living in Fukushima City were given personal dosimeters in Oct-Dec. 2011. Less than half had additional external exposures over 1mSv/yr. A few children receiving doses far above average, and the causes, were also identified. (In most cases the highest dose records were from people who left their badges outdoors for long periods, or allowed them to go through an airport Xray machine.)

(Credit: Fukushima City; annotated by SAFECAST)

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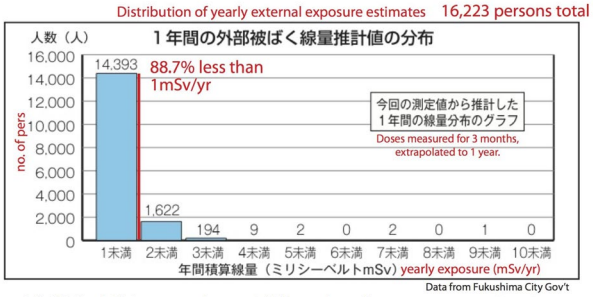
Fukushima City "glass badge" results, 2012



16,223 children under middle-school age were again given glass badges to wear from Nov. 2012 to Jan. 2013. Results showed that 88.7% had additional exposures below 1mSv/yr, a sharp decline in doses compared to the previous year.

(Credit: Fukushima City; annotated by SAFECAST)

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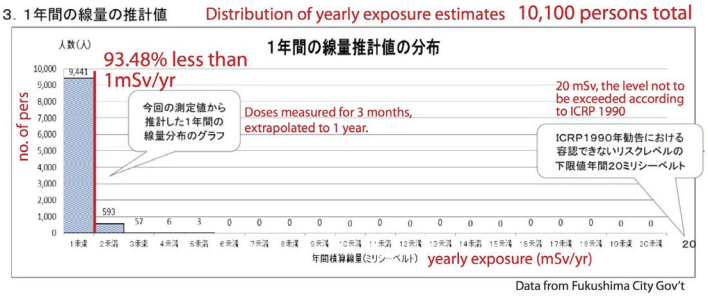
The doses showed a modest decline in 2013, based on data from 10,100 children given glass badges from Sept. to Nov., 2013. Of these, 93.48% had additional exposures below 1mSv/yr, and no child received an exposure above 5mSv/yr.

Fukushima City "glass badge" results, 2013



From Sept. to Nov., 2013, of the 10,100 children who participated, 93.48% had additional exposures below 1mSv/yr, and no child received an exposure above 5mSv/yr.

(Credit: Fukushima City; annotated by SAFECAST)

Fukushima City "glass badge" results, 2014 (no graph yet available):

Based on results from 46,436 residents, covering Sept. – Nov. 2014, 95.57% had estimated additional exposures below 1mSv/yr. The 8,616 children under 15 had an estimated average exposure of 0.08 mSv for the year, while 37,820 who were over 16 had an estimated average exposure of 0.12 mSv.

Again, we stress that these findings are not conclusive, and other towns have had slightly different experience. In 2012-2013, for instance, only 66% of the residents of the town of Date had estimated additional exposures below 1mSv/yr, though 94% were less than 2 mSv/yr. But the trend is comparable, and importantly, since fall 2011 very few people have been found to have as much as 5 mSv/yr in any town in Fukushima. We wish, of course, that personal dosimetry results were being reported clearly and in a more standardized fashion, and made more easily available.

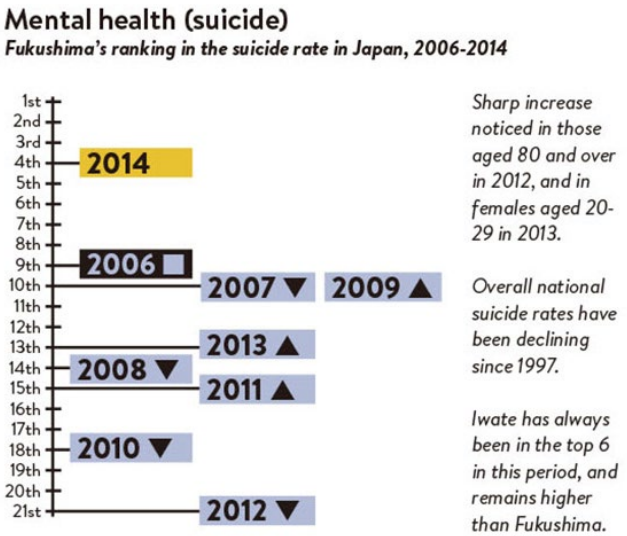
As for internal contamination, personal dosimetry is not generally available for the first weeks and months of the disaster, and in all reports so far, with the exception of Daiichi plant workers and the US military, doses for that period are based on ambient dose measurements, ground contamination measurements, and environmental and biological modeling, all of which bring uncertainties, as described above.

—Trends

In conclusion, citizens have many legitimate grievances about health testing programs, and independent oversight is still lacking. Lack of trust causes people to doubt even reliable data and conclusions. The health risks from the Fukushima NPP accident will never be zero. Nevertheless the best screening and research to date suggest that an outbreak of radiation-induced thyroid cancer is unlikely, though not impossible, and that additional internal and external doses can be kept below 1mSv/yr for the vast majority of the population if effective screening programs are continued. This may not be "safe enough" in the eyes of many citizens, but it is realistic. To achieve and maintain even this, however, will require a long-term commitment on the part of the government to conscientious, well managed monitoring of the environment, food, and health.

If past experience is any guide, we can't assume that this will happen without the constant awareness and expressed will of citizens. All should continue their efforts to gather and share information, and to press for independent oversight where needed.

2.5.4 —Mental health



(Credit: FCCJ; graphic by Andrew Pothecary)

In the wake of any disaster, psycho-social effects, such as stress, PTSD, depression, sleep disorders, chronic anxiety, physical symptoms, family problems, breakdown of community support, and others, are a known outcome. This has been true for people affected by the 2011earthquake and tsunami in Tohoku, and also for residents of Fukushima and elsewhere who have suffered from the nuclear disaster or are afraid they will. While the known physical disease risks from the levels of radiation exposure that the Fukushima public has been estimated to have encountered will be manifested in increased probabilites that will unfold over years, psychosocial effects are very real and very serious already, and affect almost the entire population to some degree.

For purposes of compensation, years ago the Japanese government adopted the concept of "disaster-related deaths." While this is an administrative category and not a medical one, by using it families and government officials seek to identify people whose lives have been cut short by stress and other negative effects of evacuation, including the more than 50 elderly who died during the evacuation itself. The most recent report, from March 4, 2015, put the toll at 1,867, making Fukushima the only disaster-hit prefecture where these deaths outnumber those caused by

injuries suffered during the earthquake and tsunami itself (1603 people).

Fukushima Minpo/ Japan Times: Death toll grows in 3/11 aftermath, March 15, 2015
http://www.japantimes.co.jp/news/2015/03/15/national/death-toll-grows-in-311-aftermath/#.VQe45hCUc3Q

The Lancet: Loss of life after evacuation: lessons learned from the Fukushima accident (Tanigawa et al, 2012)

http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(12)60384-5/fulltext?rss=yes

It is widely recognized that in comparison to most Western nations, Japan is very inadequately provided with mental health care services. Most affected towns have greatly increased their mental health counseling staff since 2011, who do their best to help evacuees. Nevertheless, elderly living alone have been found dead, sometimes after days or weeks have passed. In some municipalities, though privacy laws generally prohibit it, newspaper and milk delivery personnel have been enlisted to help keep an eye on elderly people.

The increased stresses of evacuation, isolation, and a feeling of hopelessness about the future seem to be reflected in recent suicide statistics. While the suicide rate in Japan overall has been declining since 1997, since 2011, Fukushima has seen an increase, but not in every age group.

This document from Fukushima Pref gives a good breakdown of suicides there though 2013:

Change in Suicide Rate after the Great east Japan Earthquake in 2011 and Suicide prevention Plan in Fukushima Fukushima Prefectureal Mental Health and Welfare Center April, 2014

http://www.pref.fukushima.lg.jp/uploaded/attachment/62562.docx

Fukushima's suicide rate is still not the highest in the country, but has climbed strikingly in rank compared to other prefectures since 2011. As the report makes clear, the increase is driven primarily by two age demographics: 80 yrs and older, male and female, and under 20 (male) and 20's-30's (female). The increase in the older group is probably rooted in loss of family and community support as well as health, and the increased difficulty of getting adequate care. Many young people in Fukushima, on the other hand, have expressed fears that they face a life of debilitating illness, will never be able to get married, etc., and the increase in suicides in this group may be rooted in these kinds of fears.

Basic vital statistics for Japan as of March 2015 (including suicide rate data)

http://www.mhlw.go.jp/english/database/db-hw/dl/81-1a2en.pdf

www.safecast.org