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Visual Representations of Radiation Risk and the Question of Public (Mis-)Trust in Post-Fukushima Japan

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Abstract: In the aftermath of the March 2011 Fukushima nuclear power plant disaster, an estimated 150,000 residents of Fukushima Prefecture were displaced because of both real and perceived risks of radioactive contamination. While previous research has provided ample insight into the causes and effects of the disaster, there is a lack of analysis of the production of visual representations of radiation risk. This article aims to fill this gap by exploring the question of what different cartographic representations of the types and levels of radioactive radiation are available; what information is released and how people get informed; how certain areas are considered 'safe'; and how arbitrarily government organizations draw and remove spatial boundaries of 'safe areas'. Due to the particular concern of children, who have a comparatively low-threshold radiation tolerance, the focus is on child care facilities and elementary schools. The article identifies different sources of public mistrust in the context of information seeking and sharing and addresses this issue as part of the larger question of institutionalized information processes in Japan. This also includes a prudent assessment of the increasing importance of citizen science in Japan, a society of traditionally technocratic, paternalistic, top-down approaches to public policy making. The paper concludes that because of the growing mistrust of the general public in Japan's elites, civic engagement should focus on gaining more influence on the political discourse, agenda-setting and collaborative planning and policy.

Keywords: radiation monitoring; radiation risk; visual representations; citizen science; trust and mistrust; collaborative rationality; Fukushima; Japan

1. Introduction

Unpredictable effects of technological, ecological and other threats that transcend geographical and political boundaries constitute a central theme of modern social science research on risk. The risk society thesis argues that advances in several different fields of science and technology have resulted in a variety of unique man-made risks that constitute a new type of 'world risk society' [1–6]. Without a doubt, nuclear energy technology represents such a large-scale global threat, which originated in advances in nuclear science and conscious human decisions to make use of the resulting technology [3] (p. 4). Twenty-five years after the Chernobyl accident, the nuclear meltdown in three reactors of the Fukushima I nuclear power plant in March 2011 dramatically changed the perception and acceptance of its risks in Japan. The lack of control over the risk and the lack of responsibility for the outcomes marked the end of the 'myth of nuclear safety' [7]. Even a nuclear phase-out appeared politically feasible and socially acceptable for some time [8,9]. People living in the contaminated areas were shocked by the abstract and invisible danger of radioactivity that had actually leaked from or was still hidden in the ruins of the Fukushima reactors and the cooling-water installations. As public perception of risk depends on information provided by experts and expert risk assessment is often hard for the lay public to understand or interpret, the public-expert relationship in Japan eroded massively. According to a recent media opinion survey cited by The Japan Times in March 2018, more than 80 percent of the respondents said they remain concerned with the risk of a severe accident at a nuclear power plant; more than 60 percent called for phasing out nuclear energy in the future [10]. However, as Vogl [11] (p. 208) concluded from his empirical research on nuclear risk perception, it seems that the nuclear project in Japan is happening independently of public opinion.

Individual risk perception and the resulting behavior of the population are therefore important starting points for research. Risk is understood to mean not merely a technical, quantifiable variable based on the probability of a disaster or on expectation of damage. Risk is also a feature that humans attribute to actions, situations or objects as a result of subjective and selective patterns of perception and interpretation. In doing so, individuals intuitively relate certain sources of risk to potential outcomes such as radiation damage, cause-and-effect chains or dangerous situations that they have already experienced. This individual risk assessment depends primarily on qualitative characteristics [3,11,12] ([13], pp. 2–4). Examples include the degree to which people expose themselves voluntarily to a source of risk; the perceived extent to which the threat can be controlled; the knowledge of the possible outcomes of a source of risk and its potential for catastrophic events to happen; the possibility of attributing responsibility and thus the potential preventability of risks; the horrifying extent, immediacy and (in)visibility of the effects. Individual perception is also determined by general socio-cultural values and the historical context and thus by the degree to which certain calamitous events are consciously experienced. Given the fast-moving pace of modern life and the degree of stimulus satiation from the media, there is also the danger of misjudging the dimensions of a potential threat. Consequently, it is mainly the government's responsibility to identify and assess in a transparent and comprehensible manner the risks and benefits of the available technological options. Public confidence in the assessment and regulation of risks, trustworthiness and unambiguousness of published information about risks is of fundamental importance for governments in order to raise acceptance by the lay public in any debate about risks ([3], pp. 11–12), [9].

Ultimately, this leads to the crucial question of who defines acceptable levels of risks that in principle affect humanity as a whole, with what degree of legitimacy and responsibility [14,15]. In different countries, similar exposure to risks can lead to very different conclusions regarding risk regulation. In Germany, Parliament decided after Fukushima to gradually phase out nuclear energy by 2022, whereas in Japan, a governing conservative majority still wants to retain nuclear power as a substantial element of the country's energy mix [16]: the Japanese government has a target of nuclear power accounting for 20–22 percent of the total electricity supply in 2030, which requires some 30 reactors in operation [17]. In both cases, however, the 'right of the people to decide for themselves' [18] (p. 33) cannot be replaced by legislation and energy policy making. Renn [19] (p. 64) therefore pleads for citizens to develop a more mature attitude towards risks in order to develop the ability to make sound individual judgments about risks. Free access to information is a central condition for such a process of politicization and, relatedly, of pluralization in order to produce a collective form of knowing and deciding. However, in practice, this is met by a strong tendency of the relevant policy communities to seal themselves off from policy alternatives. After Fukushima, there was much talk of the so-called 'nuclear village' (genshiryoku-mura) and its institutionally embedded power to determine the path of Japan's energy policy [9,16,20–23]: this policy community smoothly facilitates the interaction of the stakeholders and their exchange of information and resources. On the basis of a common cognitive order concerning the nature of policy problems and the required responses to these policy issues, it tends to maintain once policy paths are implemented.

Nuclear power and the radiation risk remain emotionally-charged issues despite the official announcement and close monitoring of legally-binding threshold values for radiation exposure, especially when it comes to the protection of the most vulnerable population groups, children and adolescents. While previous research has provided ample insight into the causes and effects of the Fukushima disaster [24–28], there is a lack of analysis of the production of visual representations of radiation risk. This article aims to fill this gap by exploring the question of what different cartographic representations visualizing various kinds and degrees of radiation exposure are available; what information is released and how people get informed; how certain areas are defined as 'safe' in terms of radiation; and how arbitrarily government agencies draw and remove spatial boundaries of 'safe areas'. Due to their comparatively low-level radiation tolerance, children are particularly affected, and therefore, the specific focus here is on child care facilities and primary schools, which have been subject to spatiotemporal monitoring by the Japanese government. The article then identifies different sources of public mistrust in the context of information seeking and sharing and addresses this issue as part of the larger question of institutionalized information processes in Japan. This also includes a prudent assessment of the increasing importance of the 'enlightening emancipatory power' of citizen science [29–31] in Japan, a society where policy issues still tend to be tackled and solved in a largely technocratic, paternalistic, top-down manner. As there has been a growing sense of political mistrust, disaffection with democratic institutions has also been spreading [32,33]. At the time, the nuclear disaster triggered a hitherto unknown wave of anti-nuclear demonstrations [8,9,34]. More than seven years after the disaster, however, this movement has barely any public resonance left, while the Japanese nuclear lobby, claiming that the effects of the catastrophe are controllable, is working towards a new safety myth. It is also largely ignoring the changing economics of nuclear power as safety regulations were tightened and market conditions changed significantly with the increasing use of renewable energy sources [10,17].

The article mainly draws on academic and grey literature concerning radioactive substances and their effects, handling of the Fukushima disaster by TEPCO (Tokyo Electric Power Company) and the Japanese government and the actual and received reliability of disaster-related information. In addition, it contains visual representations of radiation risk following the Fukushima disaster: government illustrations of radiation monitoring results in the form of maps and citizen-centered representations challenging those conventional representations 'from below'. As the politics of representation is a contested field and visual representations impact the way people who experienced the disaster behave, it is important to understand the techniques of data collection and visualization and their contexts.

2. Contested Radiation Measurement, Threshold Setting and Zone Identification

There are certain radioactive substances that are particularly significant as far as radiation protection is concerned, among them the highly volatile fission products Caesium-134, Caesium-137 and Iodine-131. These elements were released from the nuclear reactors in considerable quantities during the disaster [35–37]. As with all hazardous material, the impact of nuclear radiation on the human body increases as the dose increases. The physical condition of the individual and the duration of exposure are important factors because the human body has the capacity to regenerate. From patients' records of children's radiology, it is known that children in particular have a significantly lower tolerance than adults to medically-induced exposure to radiation. Moreover, increased use of CT in pediatrics has been found responsible for a small, but significant increase in future cancer risk or damage to the genome [38,39]. The reason is that cells are particularly vulnerable to radiation during their phase of division, and cell division occurs more quickly in children than in adults. For a realistic assessment of a radiation hazard, it is therefore important to have large-scale maps available that document the contamination by the relevant radionuclides. In combination with time series data, they then permit analyses of the dynamics of spatiotemporal change. This needs to include places where children are potentially exposed to external radiation. An obvious reason for adopting this principle is that it helps parents avoid contaminated places in order to reduce or even eliminate the risk of radiation exposure. Relevant information, therefore, is essential for parents to be able to decide responsibly during turbulent times.

In Germany for example, according to the Guideline for Physical Radiation Protection Control [40], the maximum permissible value for occupationally-exposed persons is 20 millisieverts per year (mSv/a), whereas for persons under the age of 18, this value is merely 1 mSv/a. A sievert (Sv), as a unit of the dose, is a direct measure of the risk of radiation-induced cancer in the human body. For persons who are not occupationally exposed to radiation, there is no value for the maximum permissible dose in Germany. In these cases, the principle applies that radiation exposure should be kept at the lowest possible level.

For the purposes of comparison, Table 1 lists some typical dose rates of natural and man-made radiation exposures. Current radiation data for Germany are published by the Bundesamt für Strahlenschutz (BfS, Federal Office for Radiation Protection). Official map series and charts contain the average dose rates established over 24 h at the 1800 measuring points of the BfS (http://odlinfo.bfs.de). In Japan, relevant information is published by the JAEA (Japan Atomic Energy Agency) in an online database. The data are collected by various government offices, using a network for measuring local doses comparable to that in Germany, as well as separate data collections that became necessary after the Fukushima disaster (http://emdb.jaea.go.jp/emdb/en).

Table 1. Typical dose rates (in millisieverts, mSv), derived from: [41].

Type of Radiation Exposure	Dose Rates
Threshold of acute radiation damage	500 mSv
Maximum permissible dose for occupationally-exposed persons	20 mSv/a
Maximum permissible dose for the general population	1 mSv/a
Abdominal computer tomography	8.8–16.4 mSv
Natural radiation exposure in Germany (average)	2.1 mSv/a
Natural radiation exposure in Germany (fluctuation)	1–6 mSv/a
X-ray lumbar spine	0.6–1.1 mSv
Dental X-ray	≤0.01 mSv
Average annual radiation dose in medical examinations	1.9 mSv/a

As a consequence of the earthquake and tsunami, substantial quantities of radioactive material were released from the Fukushima nuclear power plant through power breakdown, fires, pressure releases, hydrogen explosions and nuclear meltdown [42]. The Nuclear and Industrial Safety Agency (NISA), in charge of nuclear safety at the time, and the operating company TEPCO were widely accused of covering up the actual extent of the damage, but at least they confirmed early on that Caesium-134, Caesium-137, Iodine-131 and other substances had been detected in the area. According to an investigation carried out by TEPCO in May 2012, over 99 percent of these substances was released into the ambient air in March 2011 [43]. Leaked radionuclides were also detected later as surface contamination in several other prefectures, and raised values of the local dose rate were confirmed.

In order to minimize the potential radiation exposure, the government issued a mandatory evacuation order for the population within 20 km of the nuclear plant, affecting about 77,000 persons. Those who lived at a distance of 20–30 km from the damaged reactors were advised to leave the area voluntarily. Another government order issued in June 2011 identified further hot spots with high radiation levels outside the evacuated exclusion zone and recommended that those living there should also leave the area. This made sense, particularly outside the immediate danger zone, because ideally, the decision about evacuations should be made on the basis of measurements that concentrate on individual buildings. However, there has been disagreement among radiation experts as to the optimum radius of general evacuation zones. The Nuclear Regulatory Commission of the United States, for instance, considered an 80-km evacuation zone as necessary. The U.S. government therefore suggested that all American citizens within that distance from the nuclear power station should leave the area.

Figure 1 shows that large areas in the Fukushima region were gradually re-opened for settlement from as early as 2012. Most recently, the evacuation order was lifted for the zones in green on 1 April 2017. The strictly prohibited area extends inland in a north-westerly direction from Fukushima I into the municipality of Iitate, 50 km away. Minami-Soma, on the other hand, which lies only about 30 km to the north, was one of the first municipalities for which the government lifted the evacuation within a year of the catastrophe. Apart from a large highly contaminated zone to which it will be impossible to return for an indefinite period of time, there are small areas even relatively close to the nuclear power plant where the evacuation was repealed. These decisions are based on the decrease of the local dose rates as a result of decontamination measures. The Japanese Ministry of the Environment issues the relevant information in Japanese, as well as in English (http://josen.env.go.jp/en/decontamination/#special) [45]. The target is to reduce the radiation level in the contaminated regions initially to less than 20 mSv/a and in the longer term to less than 1 mSv/a.

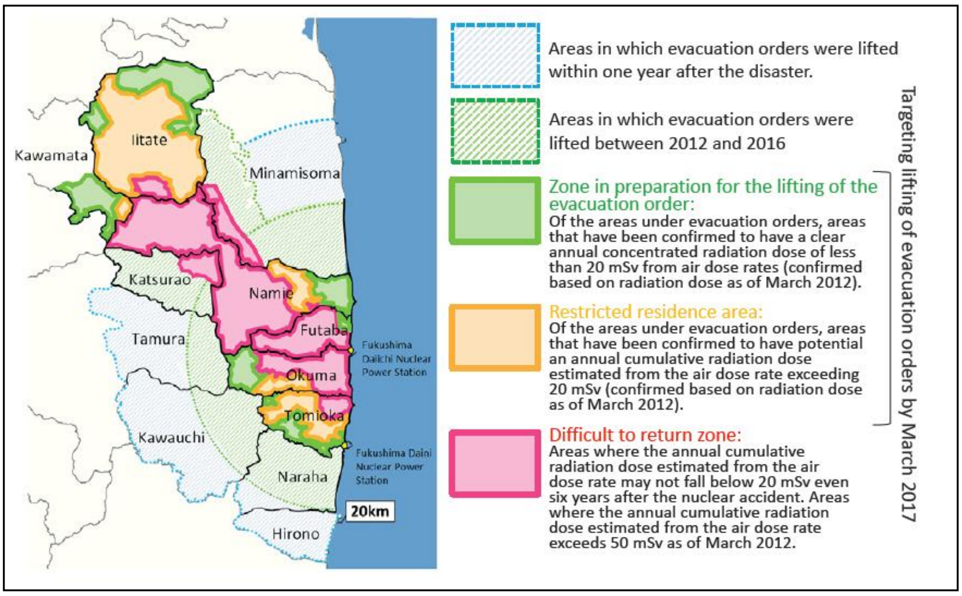


Figure 1. Evacuation areas around the Fukushima nuclear power plant by late 2016 [44].

People's trust and confidence in such decisions were early shaken by questionable government action. In order to suggest to the public that the situation was under control and even back to normal, it was the government's plan to lower the value of the radiation level threshold dose deemed harmful to children's health. On 19 April 2011, the Ministry of Education, Culture, Sports, Science and Technology announced that it was planning to increase the maximum cumulative ambient doses of radiation to which school children could be exposed outside buildings to 3.8 μSv/h. The Ministry referred to a recommendation by the International Commission on Radiological Protection [46], which considers as tolerable a radiation level within the lower bandwidth of 1–20 mSv/a in an area irradiated after a nuclear accident [47]. After eight hours outside and sixteen hours within a building with 1.52 μSv/h, the total annual radiation level would thus have remained just under 20 mSv. This dose corresponds to the threshold value for occupationally-exposed adults in Germany. As a result, there were press reports about concerned parents who initiated action to remove contaminated soil from school playgrounds by themselves, and in May 2011, the government received a joint petition from civil groups and tens of thousands of individual citizens protesting against the plan. The Ministry eventually returned to the former maximum permissible level for schoolchildren of 1 mSv/a. This means that a strategy that seemed to reduce uncertainty at first glance actually created more uncertainty and led to the emergence of local public activism.

This episode highlights the sensitivity of the matter and the people's concerns of sweeping zonings and alterations of threshold values and zones that appeared arbitrary. This also provoked a growing public skepticism of the data published by the government. Local cross-checks of government radiation monitoring results have repeatedly shown that even in supposedly safe zones, there can be radioactive hot spots. Staff and teachers in 1600 child care facilities and schools in Fukushima

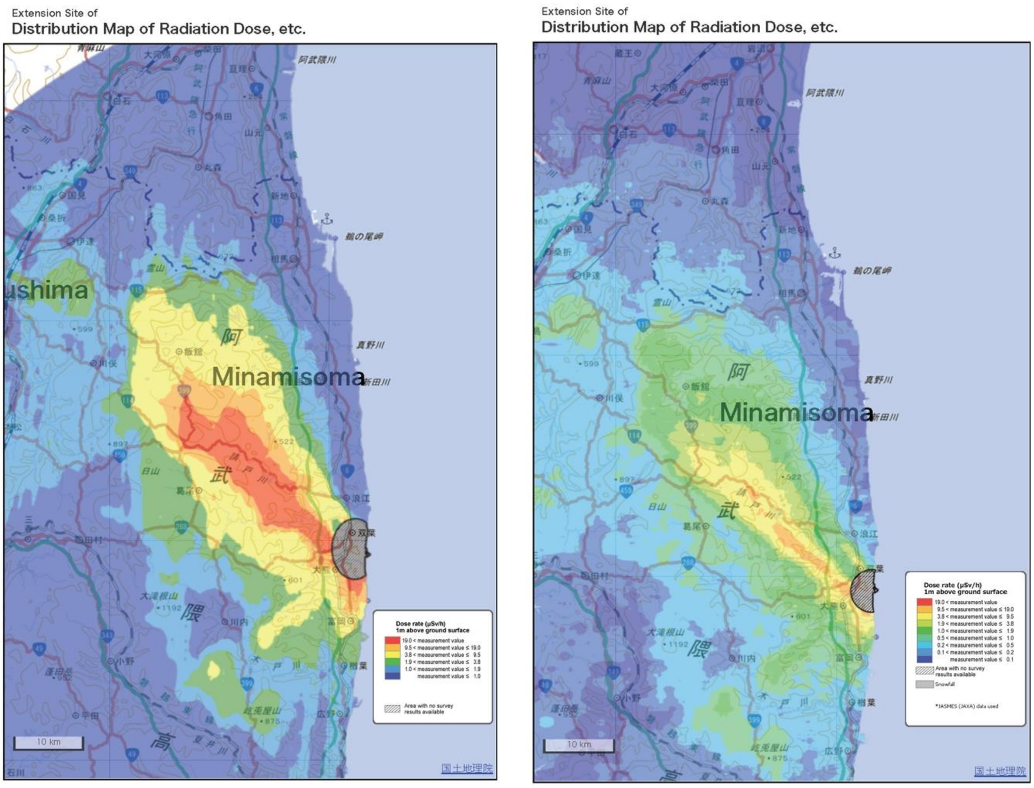
Prefecture have been equipped with measuring devices for the dosimetric monitoring of the children in their care. One important consequence of public skepticism is that despite the progress in cleaning up contaminated land, many evacuees are still grappling with the decision to return to their homes. Additionally, in many regions, reconstruction work has made only slow progress, and there is a shortage of accommodation and the necessary infrastructure. This is compounded by the economic problem that, apart from a one-off compensation sum, the amount and duration of benefit payments for refugees from Fukushima are tied to official zonings. The Japanese government has therefore been criticized for a lack of political will to take on long-term responsibility and provide adequate compensation solutions for the victims [48]. As Tateno and Yokoyama [13] point out, regaining control over their own lives and taking back their responsibility for the health of their children are essential elements for parents in coming to terms with the catastrophe. This is independent of the question of whether families with children actually intend to return to that area.

3. Visual Representations of Radiation Risks and Sources of Public Mistrust of Government

In a report for the International Green Cross (GCI), Samet and Chanson [49] come to the conclusion that in Fukushima Prefecture, up to 385,000 persons were exposed in different ways to increased radiation. In addition, psychological stress and social dislocation as a consequence of the nuclear disaster also imply dangers for their health both in the short run and in the long run [50–52]. Perrow [53] examined the radiation effects of several nuclear incidents with regard to the interests of governments and the nuclear power industry to downplay the harmful effects of radiation. He found a pattern of minimizing the damage to humans and attributing evidence of shortened life spans mostly to stress and dislocation rather than to radiation. In any case, lack of trust in the official information is a major reason why only a small number of evacuees want to return to their home towns and villages. Many of them continue to live a precarious life after the forced loss of their homes, partly caused by the fact that the government delayed definite compensation settlements [54]. Only 13 percent of the former inhabitants have returned to regions for which the evacuation orders have been suspended since 2014 [48]. Above all, it is families with children who refuse to return. As a consequence, the process of demographic ageing and decline, which has been on-going in the region for several decades, will increase sharply. In October 2011, nearly 56,500 people who originally came from Fukushima were living outside their home territory. In February 2017, their number was still 40,000, and the total number of people who fled from the disaster amounted to 123,000 [44,55].

According to Capodici [56], the GCI heavily criticized the plans of the Japanese government to lift evacuation orders for many areas tainted by the Fukushima disaster in early 2018. This would affect about 50,000 people who would then lose their entitlement to compensation. Such long-term payments are made only to refugees from Fukushima Prefecture who were forcibly evacuated by order of the authorities. 'Voluntary' refugees outside the evacuation zones were given housing benefits by Fukushima Prefecture only until the end of March 2017 [57]. The GCI argued that the Japanese government was also obliged to support those people who previously lived outside the exclusion zones, but in regions that were excessively contaminated. If the primary consideration were for the actual needs of those afflicted by the disaster, then there should be no question of an indiscriminate zoning off and re-opening at all from their viewpoint. Instead, decisions should be made on an individual basis, even if an individual just wants to avoid certain situations because of irrational fears after the traumatic events. Drawing on debates in philosophy of mind and debates about the intrinsic value of subjective color experience, Paul [58] stressed the importance of subjective knowledge about a certain experience that can only come from undergoing it, with the experience changing an individual's subjective preferences. Acknowledging the existence of the personal effects of such 'transformative experiences' might help improve political decision-making and thereby improve the relationship between the citizens and the state in the longer term. However, for the Japanese government to be able to make decisions in such a way that meets standards of rationality in the short term, the availability of reliable sources that offer sufficient justification for its decisions is certainly critical. A number of visual representations produced by government agencies, which will be introduced in the following section, give a good spatiotemporally-differentiated impression of the radiation situation in areas affected by radioactive contamination (for the effect of Fukushima on radioactivity in the sea, cf. Vives i Batlle [59]; on the pollution of food and aspects of monitoring, see the paper by Merz, Shozugawa and Steinhauser [60]).

Air measurements of local dose rates comparing the situation of 29 April 2011 and 18 November 2016 are represented as spatial interpolations in Figure 2. Radioactive substances that were released from the Fukushima nuclear power plant were transported in the atmosphere, and although they were diluted during transport, they were still traceable several thousand kilometers away. In the period 2011–2016, the local dose rate, measured in microsieverts per hour at one meter above ground, has decreased appreciably overall. As mentioned earlier, the areas where contamination was above average are in a corridor that extends in a north-westerly direction from the location of the power plant. Cartographic representations on the basis of interpolations are always abstractions from reality, and the data classification and representation method that are used here are therefore to some extent simplifications and entail uncertainties for those people affected. Exact monitoring results provided by the Secretariat of the Nuclear Regulation Authority (NRA) and the Fukushima Prefecture administration have been published with greater location accuracy on the NRAwebsites ('Monitoring Information of Environmental Radioactivity Level', available online at http://radioactivity.nsr.go.jp/en/). To achieve this, the area of the prefecture was divided into 4 × 4 km grids and 1–6 measuring stations were installed in each section if it was an urban or residential area, making a total of 1864 measuring stations. The local dose rate was regularly measured at one meter above ground, and the raw data and cartographic visualizations were published. To illustrate the spatiotemporal dynamics, the results for the first (12–15 April 2011), sixth (13 May–5 June 2013) and eighth (13 May–10 June 2015) data collections have been juxtaposed in Figure 3. The dot representation enables even the lay public to understand the extent of contamination in a specific locality.



(**a**) (**b**)

Figure 2. Local dose rates measured in Sv/h (**a**) on 29 April 2011 and (**b**) on 18 November 2016 [61].

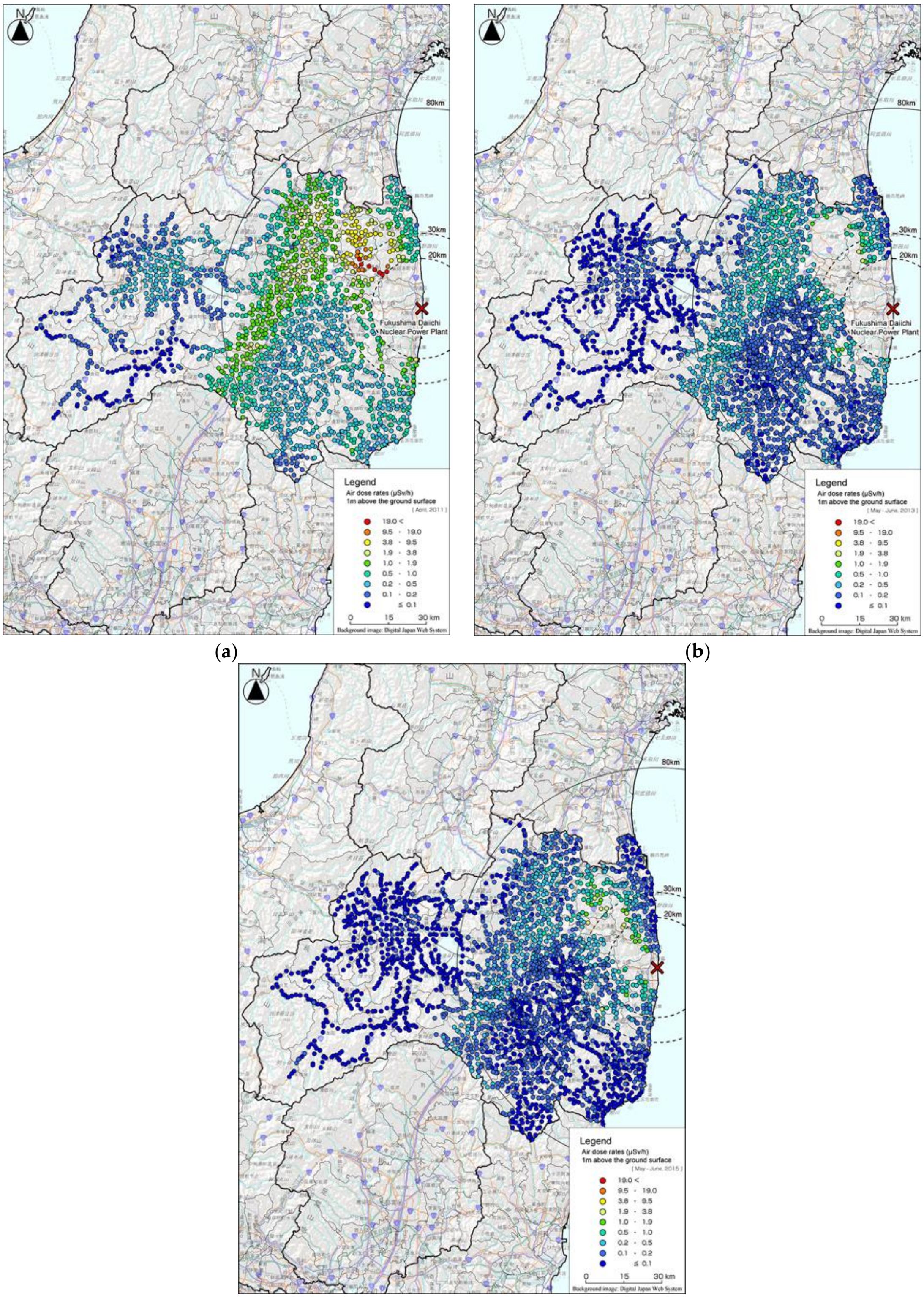


Figure 3. Local dose rates in measuring stations in Fukushima Prefecture (in μSv/h) during the periods: (**a**) 12–15 April 2011; (**b**) 13 May–5 June 2013; (**c**) 13 May–10 June 2015 [62].

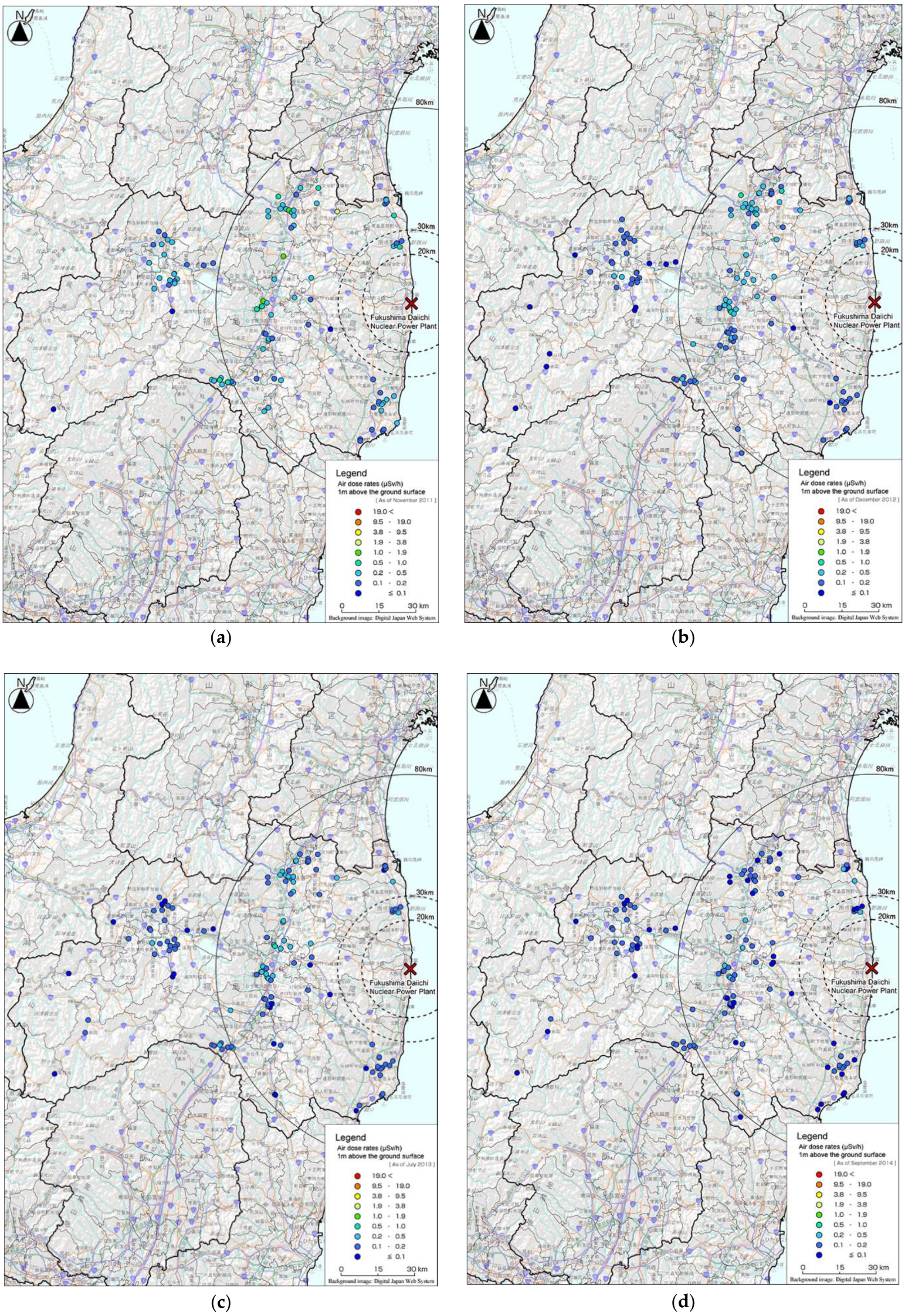


Figure 4. Results of radiation monitoring for child care facilities in Fukushima Prefecture as of (**a**) November 2011; (**b**) December 2012; (**c**) July 2013; (**d**) September 2014 (in μSv/h) [63].

The particular vulnerability of children requires a look specifically at child care facilities and schools, for which address-specific time-series measurements are available in the form of raw data and cartographic representations ('Results of Environmental Radiation Monitoring for Child Welfare Institutions', (available online at http://emdb.jaea.go.jp/emdb/en/portals/1010104000/). This reveals at least a certain degree of government awareness of the specific informational needs of families with children. Figure 4 shows the results of the radiation monitoring for child care facilities in Fukushima Prefecture at four different times between 2011 and 2014. In compliance with international standards, the measurements were taken at one meter above ground. The data demonstrate that, on the whole, people in facilities outside the 20-km exclusion zone did not receive dangerous doses. In most measuring stations, the level of radiation had decreased to the level of natural radiation exposure as early as April 2014. In Japan, this is approximately 0.99 mSv/a including cosmic, terrestrial and incorporated radiation apart from radon [65]. Additional measuring at 50 cm above ground has confirmed this general downward trend.

Processing the data on the radiation situation in primary-school locations provides further insights. In addition to local dose rates at one meter above ground in school grounds in April 2011 (left), Figure 5 also shows specific data on the activity concentration of radio nuclides Caesium-137 and Iodine-131 in ground air, measured in Becquerel per cubic meter (Bq/m^3). These data were obtained from dust and soil samples. According to these samples, there was no activity concentration of Caesium-137 in most locations. This result may have some sort of calming effect on the people in the contaminated areas because Caesium-137 is a long-term source of radiation with a half-life period of 30 years. In a few locations, however, an increased activity concentration of Iodine-131 was detected. Minami-Soma City Haramachi Daiichi Elementary School had the highest reading at 8.8 Bq/m^3, but given its very short half-life period of eight days, Iodine-131 represents a comparatively minor source of radiation danger. For comparison purposes: the activity concentration of natural radioactive substances in the air outside buildings is normally in a range between 1 and 10 Bq/m^3. According to the former Japanese regulatory body, Nuclear and Industrial Safety Agency (NISA) [66], the total amount of Iodine-131 and Caesium-137 that was released was approximately 10 percent of the radioactivity released at Chernobyl in terms of an iodine equivalent. Estimates of the United Nations Radiation Protection Committee suggest that Fukushima will not increase demonstrably or by a quantifiable measure the general risk of cancer in Japan [51]. However, Hippel's [52] estimated number of resulting cancer deaths in the Fukushima area from contamination due to more than 1 curie per square kilometer is 1000.

Overall, the information policy of the operating company, the regulatory bodies and the government immediately after the disaster was initially reluctant and inadequate, and coordination was insufficient [67]. In addition to the inability to act and a lack of determination in the various agencies at the time of the catastrophic events, this is a central cause of the mistrust that has become widespread among the victims [9,13,68]. The absence of up-to-date data immediately after the earthquake and tsunami is, of course, due in part to the destruction of monitoring stations, but it is also due to a weak crisis management inherent in the system and a flawed communication of radiation risk. It took some time for new monitoring systems to be installed that allowed for the gathering, publishing and regular updating of comprehensive data about radioactivity and radiation effects. Needless to say, the system is not all-encompassing, and individual houses or routes to public buildings such as schools cannot be represented, especially in interpolations.

Figure 5. Local dose rates (in μSv/h) (**a**) and activity concentration of radio nuclides Caesium-137 (**b**) and Iodine-131 (in Bq/m^3) (**c**) in school grounds in Fukushima Prefecture in April 2011 [64].

The serial data curve of the published data of local dose rates at various measuring points shows that initially, there was a massive release of radionuclides. Since then, the activity concentrations, as well as the local dose rates have quickly returned to normal levels. One reason for this is that, according to calculations by Ten Hoeve and Jacobson [50], 81 percent of radioactive precipitation fell over the Pacific Ocean. On the other hand, contaminated cooling water that found its way into the open sea and into the ground water remains a long-term challenge. For that reason, the dense monitoring network is maintained on a continuous basis. The question remains, though, whether this information is regularly made available to the general public, or whether their confidence in official information sources is not deeply compromised by earlier scandals and regulatory failures, the lack of reliable information during the early stages of the disaster and poor coordination among TEPCO and government agencies. Third-party verification of government radiation monitoring outside the nuclear power plant itself carried out by NGOs such as Greenpeace and Safecast also shows a mixed picture. According to Safecast [67] (p. 29), ambient radiation levels recorded by volunteers generally match official data within a reasonable margin of error. By contrast, Greenpeace has found that official monitoring stations systematically underestimate both the risks and extent of radioactive contamination [69]. The sources of public mistrust in the context of information seeking and sharing are thus manifold. The next section will address this issue as part of the larger question of institutionalized information processes in Japan.

4. Data Availability and Public Information Policy: A Question of Trust

The informal and non-transparent networks of the 'nuclear village' have been extensively analyzed elsewhere. In Japanese studies and with regard to other policy fields, it is more generally referred to as the 'developmental state' or 'network and clientelistic state' model, arguing that policy actors are deeply embedded in long-term relationships of mutual obligation with special interests [20–23,70,71]. The specific configurations and memberships of such policy communities differ by field. The focus here is on the role played by the big energy suppliers and their lobbying organizations, by ministerial bureaucracies, above all the Ministry of Economy, Trade and Industry (METI) and the Nuclear and Industrial Safety Agency (NISA), and by politics, especially the pro-business and pro-nuclear Liberal Democratic Party of Japan (LDP). In addition, there are allegedly independent actors such as representatives of the influential mainstream media and renowned academics, groups of actors who were repeatedly suspected of providing a façade for manipulations in the interest of the 'nuclear village'. Such exclusive policy networks operating in specific policy fields are highly problematic from the point of view of democracy theory. They are based on institutionalized patterns of power and authority and the clear delineation of insider and outsider group positions [33,72]. Collusion, poor regulation and a lack of transparency and control fueled by vested interests, combined with overconfidence in the controllability of the technology, bred carelessness in the nuclear industry as it failed to correctly implement even 'the most basic safety requirements' [73].

The main problem here is the co-option of academic experts by policy makers and other influential actors. Misleading or deliberately untrue expert input has been motivated by certain incentives built into the system of commissioning consulting services by government agencies and the industry itself. For example, appointment to a regulatory advisory committee adds to an expert's professional standing, and financial interests and workplace politicking may also play a role. Figueroa [9] (p. 77) reported that most anti-nuclear researchers were removed from an energy policy advisory board to the government by the ruling LDP in March 2013 and replaced with nuclear energy-friendly advisers. The so-called 'government scholars' or 'academic flunkies' (goyô gakusha) have a very keen interest in the allocation of additional research funds or expert appraisal assignments awarded by governmental bodies or private sector companies. An overzealous desire to comply with certain political or administrative demands or directives then often results in misleading or flawed expert advice, which intentionally deceives the public as the focus is on justifying projects rather than critically scrutinizing them. At the same time, there is only very little risk of professional, financial or legal consequences. It should be noted that this is not a specifically Japanese phenomenon, as Flyvbjerg [74] and Flyvbjerg, Bruzelius and Rothengatter [75] have shown with reference to public construction projects. Governance frameworks not vulnerable to manipulation by organized interests and changed incentives for experts are essential in order to change towards better practice that rewards honesty.

The co-option of media operations by political or economic interests is also highly problematic. Various mechanisms of (self-)censorship in the Japanese press are well known, particularly the system of press clubs with its interdependencies between journalists and governmental actors. In view of the way the press is organized, Hall [76] spoke early on of 'cartels of the mind' and Freeman [77] of 'information cartels': 'closed shops' of politicians, ministries and journalists that follow their own rules in information gathering, processing and disclosing. It becomes clear that regulatory roles become available for these actors. According to Hall [76] (p. 73), this undermines a sound democratic culture characterized by critical thinking, controversial debate and transparency. The duty to provide information to the public is interpreted less as a duty vis-à-vis the people than as an obligation to observe the requirements of the 'national interest' as defined by those actors in power.

The nuclear sector in particular, which serves the 'national interest' in a stable and affordable energy supply, has a long history of reactor breakdowns and cover-up scandals. Long before the Fukushima disaster, the credibility of the Japanese elites would have benefited from a wider public debate about the risks of this technology. Blind faith in modern technology, ideological blinkers, lobbyism and camouflage tactics after breakdowns or reportable events, for which TEPCO in particular was repeatedly criticized in the past [78,79], certainly do nothing for much needed confidence building. This context helps us to understand the public mistrust in the validity, reliability and objectivity of official data on radioactivity and radiation effects, something that causes concern about the state of Japan's liberal democracy. Media reporting about Fukushima was internationally considered inadequate, and Reporters without Borders' evaluation of the freedom of the press in Japan has been seriously downgraded in recent years: within a single year, between 2012 and 2013, Japan slipped 31 places down on their index to 53rd place (out of 199 countries). After the so-called State Secrets Law had come into force in December 2014, Japan's ranking slipped even further. In 2017, it was down to 72nd place (out of 180 countries) [80]. The betrayal of certain state secrets has since been punishable by long-term imprisonment, and the consequence, foreseen by many critics, is that sensitive topics such as Fukushima are covered only very cautiously or not at all [81,82]. Thus, the continuous threat to press freedom, most recently discussed in much more detail in a volume edited by Kingston [83], remains a major challenge to democracy in Japan, for which a free press, media diversity and trust in the state's institutions are essential foundations. The non-transparency of 'nuclear village'-like policy communities supports a state of low visibility of critical issues and a lack of policy alternative debate with negative consequences for citizens' participation in the political process. Low voter turnout in general elections might well be interpreted as an indication of a deficit of the legitimacy of Japan's liberal democracy favoring non-transparent particularistic legislative organization [33].

Since Fukushima, discussions have begun in Japan, but also elsewhere, about the concept of an open and transparent citizen science as an alternative to the authoritarian claims of the public administration and its overly submissive academic and media elites. This could make a real contribution to the (re)vitalization of Japanese democracy by making the acquisition and distribution of information the activity of citizens who are in continuous dialogue with each other. With growing education and knowledge, growing affluence and the wide availability of modern information and communication technologies, new forms of networking and participation have become possible and indeed desirable, particularly in view of current debates about a 'lying press', 'fake news' and 'alternative facts'. Citizen science projects must, however, adhere to the generally-accepted standards of research practices and scientific integrity. These include above all scientifically well-grounded methods of experimental design, data generation and analysis, transparent documentation and publication of the results, as well as openness in discussing their work with other scientists and with the public. To comply with these demands, citizen science projects usually depend on some sort of independent scientific support because non-scientists on their own are easily overwhelmed by the complexity of the task.

Aldrich [34] (p. 7–9] mentions the fact that, since Fukushima, interest in citizen science has grown in Japan and refers to the online platform Safecast (https://safecast.jp) as a successful example: a project developed by Japanese citizens for measuring, collecting and publishing data on radiation exposure, which is independent of official statements, free of comments and thus politically neutral [84–86]. The measuring of radioactivity is carried out with specially-developed Safecast radiation detectors that are linked to GPS and the Internet, so that data can be obtained every five seconds and then uploaded directly to their homepage. Figure 6 gives an example of the spatial interpolation of data that were gathered on 7 March 2017. The data are considered to be particularly reliable, and the public availability will also help people living at some distance from the evacuation zones to make their individual risk assessments. Hultquist and Cervone [87] therefore come to the conclusion that Safecast has massively encouraged citizen participation, promoted explorative learning, knowledge about radioactivity and radiation and hence self-determined decision making on the basis of reliable information.

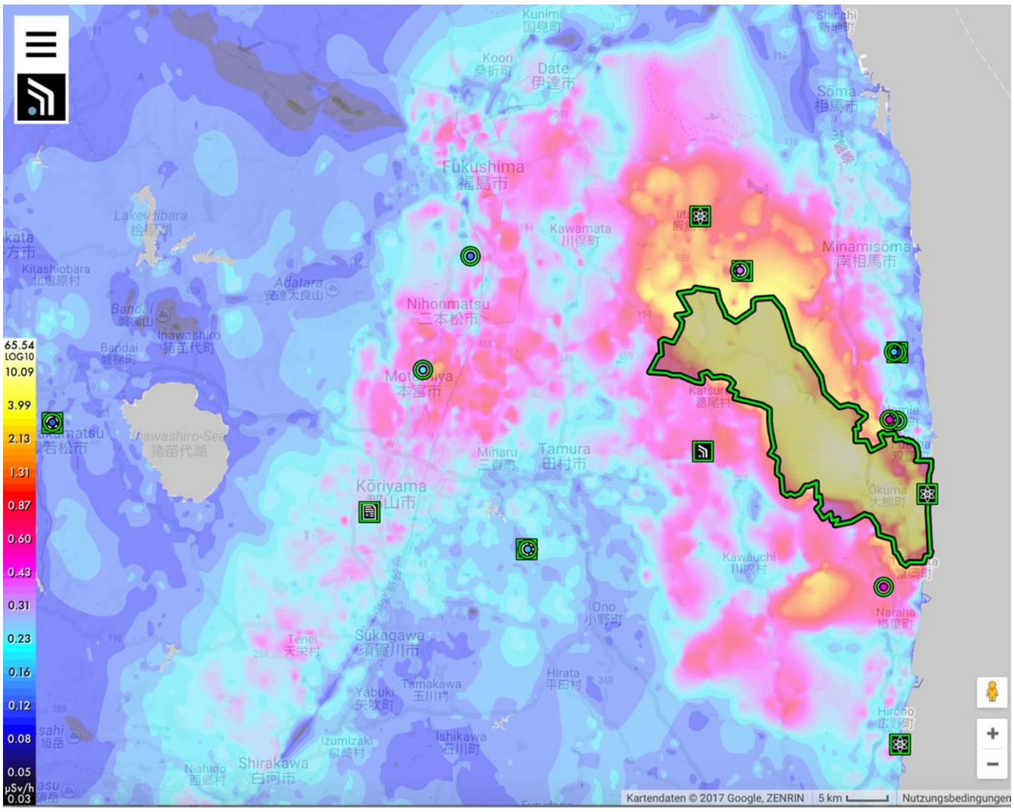


Figure 6. Local dose rates according to Safecast measurements on 7 March 2017 (in μSv/h) [88].

The lack of trust in the official information policy and the need for immediate action resulting from the experience of tens of thousands of people were highly motivating factors for the Safecast activists. Safecast, as an alternative organization, encourages participation from and offers information to non-scientists, collectively generating and storing knowledge, which becomes freely available. The individual reception and evaluation of such information, however, requires a willingness to acquire some basic technical and scientific knowledge of how to analyze and interpret radiation exposure data. The spread and consolidation of citizen science represents a big individual and structural challenge because of a lack of financial resources for most projects, especially in Japan, and because the willingness of people to participate is not very strong [31]. Hultquist and Cervone [87] suggest the need for closer collaboration or even a merger of state-run and citizen-centered monitoring systems.

At any rate, mutual trust and respect and the ability to communicate, possibly with the support of neutral mediators, are indispensable if the divide between politics, science, the media and the public is to be overcome [89]. Suspicion and the experience of unmet or violated expectations are central factors that contribute to the emergence of mistrust [90], and mistrust leads to weakening of relationships, lack of cooperation and even deception [91]. However, given the trajectory of its planning and policy culture, it would be naive to think Japan's politics of information and representation are easily transformed into a new elite-public partnership.

5. Conclusions

Human rights and the rule of law, promoting a just society and active participation of each individual in society, transparency, openness and accountability are the very foundations of liberal democracy. They must be articulated and safeguarded for the sake of future generations. That is why it is so important to scrutinize the interests of all state and business actors throughout the subsystems of Japanese society. Civic engagement in general and citizen science in particular can make a valuable contribution by firmly opposing any abuse of research and the media for the legitimization of particular interests. To satisfy the legitimate demands for genuine citizen participation and more reliable information, politicians, officials, scientists and media professionals will have to engage in a joint effort to make their actions transparent, to share information and to communicate openly, as well as to provide opportunity structures for citizens' participation in decision-making processes. Japan's policy communities operate in specific political fields and are largely detached from the views and interests of outsiders; this has undermined the mutual trust between power elites and society. To remedy this, policy communities would have to become more accessible at least. Politicians ought to play a much more active role in this, but most of them are too deeply implicated in their role as brokers of particular interests. Furthermore, policy communities have no genuine interest in the public sphere, in parliamentary argument or in alternative, let alone rival, policies. As a consequence, decisions are largely made outside Parliament because relevant action is negotiated in advisory committees or informal circles, and the general public is rendered increasingly apolitical.

The fact that the government is putting pressure on refugees from Fukushima by gradually lifting evacuation zones is in itself morally questionable in view of the trauma caused by the nuclear catastrophe. In this situation, a better understanding of the specifics of individual risk perception and hence of potentially irrational behavior would appear necessary. It is well known, after all, that the perception of people without a scientific background tends to be influenced by irrational and extraneous considerations, even if they have developed an overall mature attitude towards risks. For those people who were directly affected by the disaster, 'there's a dimension of the subjective value that can only be grasped by having the right sort of experience' [92] (p. 498). Therefore, absence of such experience is an obstacle to addressing it adequately, and people's perceptions should be taken into account very seriously by the authorities [9] (p. 77). When making moves in this direction, there is potential to reduce the difference between lay opinion and expert opinion testimony. Nuclear power stations are regarded as particularly dangerous by many people because the risks they pose are perceived as threatening, uncontrollable, catastrophic and imposed by outside forces. The fact that children are particularly vulnerable to nuclear exposure ought to be given due consideration, not least in the matter of a final compensation for families affected by the Fukushima disaster who do not wish to return to contaminated grounds. Moreover, if the commitment is still valid that radiation exposure should be kept as low as possible, then there must not be a minimum level for persons who are not professionally exposed.

As the degree of public concern with the handling of the Fukushima disaster remains high, the government's ability to deal with these concerns must be questioned. Rational political decision-making with its reliance on expert knowledge alone might well be doomed to failure if the existence of individual 'transformative experiences' [58] is ignored on the grounds of principle. Innes and Boher [93] advocated the idea of 'collaborative rationality', bringing the various experiences and perspectives of the affected interests to the table to deliberate on the problems they face together. Of course, certain requirements must be met (e.g., all participants must be fully informed and able to express their views following clearly-defined procedures), and there are limitations (e.g., when an immediate decision is needed to protect life). However, declaring collaborative dialogues inappropriate for certain policy fields per se ignores the complexities of modern risk societies and the ways political power is legitimated. Above all, the decisions collaboratively rational processes reach are rational, 'not only in the sense of being well informed and in the spirit of democracy, but also in the sense that they represent a collective form of knowing and deciding' [93] (p. 9).

Finally, it is clear that the calamitous Fukushima event initially triggered a general debate about a nuclear power phase-out, but the anti-nuclear movement has lost its momentum [7,9,16]. Despite new regulations to improve the safety of nuclear reactors and on-going security checks in Japanese nuclear power plants, there is little evidence in society and in the political sphere that enough lessons have been learned about the handling of nuclear energy. Japan's power elites still show little interest in a genuine dialogue with the public; energy policy is heavily influenced by lobbying; and the sneaking suspicion that they are given false information leads to disenchantment, disillusionment and lethargy in far too many citizens. This is a problem (amongst many others) that is resulting in a decreasing turnout at national and local elections. Civic engagement in Japan should therefore focus on gaining more influence on the political discourse and its topics, on political agenda-setting and collaborative planning and policy. A more critical role for the domestic mass media is essential to more deeply embed nuclear issues into the larger public discourse; to prevent the nuclear industry from returning to business as usual; and to build a broad societal consensus on the way forward. It is one of the great challenges in the 'risk society' to overcome the inability of traditional structures to deal with risk and uncertainty. Central to this, it seems, is a re-configuration of the complex and dynamic relationship between the citizen and the state.

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