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Temporal Citizen Science After Fukushima

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This article investigates how various citizens framed the temporality of the 2011 Fukushima Daiichi nuclear disaster through the production and representation of data on soil contamination. Drawing on Beck's risk society, Jasanoff's civic epistemology, and Edwards' knowledge infrastructures, this study uses the Minna-no Data Site (MDS), or Collective Database of Citizens' Radioactivity Measuring Labs, to foreground the role of citizen science in shaping its temporality of the disaster. In doing so, it illuminates how MDS generated and processed its data as a political resource for intervening in the dominant temporality of the disaster secured by the Japanese state. Ultimately, this article contributes to the reimagination of citizen science via temporal pluralism.

Keywords: risk society, citizen science, temporality, Japan, Fukushima Daiichi nuclear disaster

On March 11, 2011, a magnitude 9.0 undersea earthquake and the resulting tsunami devastated the northeastern part of Japan. The damage from the tsunami caused a power outage and resulted in the meltdown of three reactors at the Fukushima Daiichi nuclear power plant, which released a tremendous amount of radioactive materials into the environment (e.g., Fujigaki, 2015). In the wake of the triple disaster, however, there was very little publicly available information on environmental radiation. Because of the combination of the earthquake and tsunami, the Japanese state's information infrastructures, such as radiation-monitoring posts, broke down (The Asahi Shimbun, 2011). Furthermore, the Japanese state failed to use the information it had obtained through its System for Prediction of Environmental Emergency Dose Information (SPEEDI) during the initial evacuations, although the state later apologized for not promptly releasing the information. Given this lack of information, it became imperative for people to know the present level of environmental radiation to ensure their health and safety (Tateno & Yokoyama, 2013).

Notably, it is not a new phenomenon that such a lack of information encourages various people and organizations to independently produce data and information on environmental radiation. For example,

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Japanese citizens measured and monitored environmental radiation after the Chernobyl nuclear disaster of 1986 because they felt that sufficient information on radioactive materials from the Chernobyl power plant was lacking (e.g., Abe, 2020a; Sakuma, 2015; Takagi, 2015). What differentiated the Fukushima disaster from previous nuclear disasters was that the former was arguably the first "known" major nuclear disaster since digital media became embedded in everyday life (e.g., Abe, 2014; Takano, Yoshimi, & Miura, 2012). Following the Fukushima disaster, various people not only measured environmental radiation using dosimeters but also processed and circulated the resulting data via the Internet and social media (e.g., Feldhoff, 2018; Kera, Rod, & Peterova, 2013; Wynn, 2017). While some people and organizations published measurement data online even before the Fukushima disaster (e.g., Ishikawa, 2012), the Fukushima disaster witnessed a surge of various people engaging in the production and circulation of digital information on radiation. Although measuring environmental radiation was largely the state's responsibility before the Fukushima disaster, digital media offered people and organizations a way to produce and share information on environmental radiation in Japan (e.g., Morita, Blok, & Kimura, 2013).

Many scholars have observed the role of digital media and investigated how citizens use digital technology to create geographic information on environmental radiation from their collected scientific data through the citizen science framework (e.g., Berti Suman, 2019; Hemmi & Graham, 2014; Plantin, 2015). Among the burgeoning literature on citizen science practices (e.g., Fan & Chen, 2019), there has been a growing body of research on geographic citizen science (e.g., Connors, Lei, & Kelly, 2012; Hachmann, Arsanjani, & Vaz, 2018; Haklay, 2013; Trojan, Schade, Lemmens, & Frantál, 2019). Skarlatidou and Haklay (2021), for example, contextualized geographic citizen science at the intersection of the different fields of volunteered geographic information (VGI) and citizen science and aptly characterized it as a set of practices involving "the utilisation of geographic information technology to collect, analyse and disseminate data collected by non-professional participants in a systematic and objective way" (p. 4). It is important to examine the role of citizens in shaping spatial data, given that much research has shown that the rise of the Internet has facilitated the growth of VGI (e.g., Goodchild, 2007). In the wake of the disaster, it was particularly urgent for citizens to know where radiation levels would be high, partly because even radiation levels in different objects, such as urine and food, among others, are more or less affected by the location where people and foods are embedded. Accordingly, multiple researchers thus far have examined the role of digital media in the notion of geographic citizen science (e.g., Feldhoff, 2018; Plantin, 2014).

With few exceptions (e.g., Wynn, 2017), empirical work in citizen science has not interrogated the role of citizens in shaping temporal information through the use of digital media. While the temporality of a disaster should not be taken for granted as a single and universal sense of time (e.g., Law, 2015; Mol, 2003; Omura et al., 2016), what constitutes the temporalities of the nuclear disaster in the digital age, who should participate in defining the end of the disaster, and by what means? Given that nuclear disasters unfold within particular temporal frames, how do citizens or nonexperts engage in the politics of the disaster's temporalities using their collected data in the digital age? Only by addressing such questions can one begin to understand what is called "post-Fukushima" Japanese society. Accordingly, this study extends the existing scholarship by taking temporality and digital media as an inroad to understanding citizen science after the Fukushima disaster.

In practice, the temporality of the Fukushima disaster has in recent years become a major symbolic battlefield for citizen science projects in the disaster recovery process for at least two reasons (e.g., Abe, 2015; Minna-no Data Site, 2019). First, it was difficult for geographic citizen science practitioners to play a significant role in post-Fukushima Japanese society, where environmental radiation levels naturally decayed with time (Abe, 2015). Furthermore, the Japanese state built and rebuilt its information infrastructures, allowing people to adequately obtain geographic information on environmental radiation (Abe, 2015). Compared with the immediate aftermath of the disaster, the spatiality of the disaster is no longer a point of contention. That being said, second, and perhaps more importantly, there is still controversy over the temporalities of the disaster. Although the Japanese state has declared its temporal order by touting recovery from the triple disaster, it is crucial to note that the state of nuclear emergency, which the Japanese state declared on March 11, 2011, has not yet been lifted (e.g., Koide, 2019). Nevertheless, the Japanese state ended the government-sponsored Great East Japan Earthquake Memorial Ceremony in 2021 (Kodama, 2021), creating a loss of opportunities to think about the disaster every March. After the 10th anniversary of the triple disaster, it became imperative to discuss who should join the conversation about the temporalities of the Fukushima disaster and by what means.

This study, thus, proposes the concept of "temporal citizen science" to explore how citizens or nonexperts use their environmental data to engage in the politics of the disaster's temporalities in the digital age. Temporal citizen science can be defined as an extended scientific work of geographic citizen science undertaken by a wide variety of citizens where the generated digital data involve the representation of the disaster in the future. It is important to note that the notion of temporal citizen science involves the production of geographic data; therefore, temporal citizen science should be understood as an extended practice of geographic citizen science. Regarding the future as a key component of temporal citizen science, Urry (2016) pointed out the relation between the future and power by noting that "a key question for social science is who or what owns the future—this capacity to own futures being central in how power works" (p. 11). Accordingly, what differentiates temporal citizen science from geographic citizen science is that the former foregrounds the nonspectacular role of citizens in intervening in power relations involving the politics of the disaster's temporalities using digital data.

To explore the case in which citizen science, disaster temporalities, and digital media converged after the Fukushima disaster, this study focuses on examining the Minna-no Data Site or Collective Database of Citizens' Radioactivity Measuring Labs (MDS, thereafter) and its East Japan Soil Becquerel Measurement Project in particular. Of the various grassroots organizations and networks that generated environmental radiation after the Fukushima disaster (e.g., Kenens, Van Oudheusden, Yoshizawa, & Van Hoyweghen, 2020), MDS provided a strong advantage for this study. As a national network of independent citizen science initiatives, MDS not only created a publicly available database on soil contamination after the Fukushima disaster in its East Japan Soil Becquerel Measurement Project but also tactically used digital technology to produce estimated data on *future* soil contamination levels. More specifically, MDS used its resulting database as a fundamental scientific resource to create a radiation map of the future through the tactical uses of digital media. Focusing on MDS contributes to reimaging citizen science via temporal pluralism.

In the next section, this study elaborates on temporal citizen science by reviewing three theoretical frameworks and briefly describes the method used in this study. The third section investigates how citizens created their data on radiation, particularly on soil contamination by describing the historical trajectory of MDS. Finally, the fourth section analyzes MDS's radiation map of the future and discusses how MDS envisages the future temporality of the disaster through data representation practices.

Theoretical Frameworks and Methods

Work in citizen science has done much to reveal the role of citizens or nonexperts in the production of scientific claims in contemporary society (e.g., Cavalier & Kennedy, 2016; Collins & Evans, 2007; Dickinson & Bonney, 2012; Irwin, 1995; The National Academy of Sciences, 2018). In particular, much scholarship has increasingly investigated the role of citizens in shaping scientific information in the contexts of disaster response or uncertain conditions (e.g., Brown, 1997; Callon, Lascoumes, & Barthe, 2009; Kuchinskaya, 2011, 2019; Wynne, 1992).

In his book *Risk Society*, Beck (1992) referred to intersecting concerns linked to health, science, and technology and discussed the role of citizens or nonexperts in modern society. He pointed out that the overdevelopment of science and technology creates an unprecedented risk in contemporary society, where citizens or nonexperts play a greater role in shaping scientific knowledge because they become "small, private alternative experts in risks of modernization" (Beck, 1992, p. 61). Beck (1992) further characterized contemporary risk consciousness in relation to time under the condition of a risk society as follows:

> The center of risk consciousness lies not in the present, but *in the future*. In the risk society, the past loses the power to determine the present. Its place is taken by the future, thus, something non-existent, invented, fictive as the "cause" of current experience and action. (p. 34; emphasis in original)

Beck (1992) indicated that "the power to determine the present" (p. 34) depends on how we perceive future risks. Beck (1992) did not elaborate on the role of citizens in envisaging and representing the future with their knowledge of contemporary risks using digital media but discussed the politics of defining contemporary risks in relation to the power relations between institutions and citizens, noting that:

> As long as the citizen does not possess the means to make the invisible threat to their life visible, all the power to define global risks lies in the "hands" of the institutions (experts and legal systems, industries, government, etc.). (Beck, 2016, p. 100)

His view of contemporary risk consciousness and the role of citizens in performing against the power of institutionalized risk definition provides a fundamental theoretical framework for temporal citizen science.

The question, then, is how the sense of future risk is tested and communicated among citizen science practitioners and beyond. Jasanoff's (2005) civic epistemology offers a rich resource for addressing this question. Jasanoff (2005) referred to civic epistemology as follows:

> Civic epistemology refers to the institutionalized practices by which members of a given society test and deploy knowledge claims used as a basis for making collective choices. Just as any culture has established folkways that give meaning to its social interactions, so I suggest that modern technoscientific cultures have developed tacit knowledge-ways through which they assess the rationality and robustness of claims that seek to order their lives…These collective knowledge-ways constitute a culture's civic epistemology; they are distinctive, systematic, often institutionalized, and articulated through practice rather than in formal rules. (p. 255)

By the notion of civic epistemology, Jasanoff (2005) foregrounded collective public reasoning as a practice by which citizens assess and understand the rationality of knowledge claims. While Beck (1992, 2016) contextualized citizen science practitioners in relation to the politics of risk definition, Jasanoff (2005) observed the role of political and technoscientific cultures in shaping an institutionalized form of deliberation and reasoning through which citizen science practitioners make knowledge claims. Therefore, civic epistemology provides a resource for analyzing how citizen science practitioners test and develop their knowledge claims about the temporality of the Fukushima disaster through their citizen science practices in political and technoscientific cultures.

Finally, this study further builds on infrastructure studies (e.g., Bowker, Baker, Millerand, & Ribes, 2010; Finn, 2018; Offenhuber, 2017), particularly knowledge infrastructures (Edwards, 2010; Edwards et al., 2013; Jalbert, 2016) to explore MDS's database on soil contamination. Edwards (2010) referred to knowledge infrastructures as "robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds" (p. 17). While key elements of MDS's database on environmental radiation include various human and nonhuman actors, such as measurement devices, measurement protocols, and data management systems, this study focuses on the social aspect of the knowledge infrastructures of MDS's database in terms of what Brand (1999) termed "long now," by which MDS creates specific knowledge about the temporalities of the Fukushima disaster through articulating future risks. In doing so, temporal citizen science practitioners advance particular ways of representing the future by promoting their particular normative ends.

With the three theoretical frameworks discussed above, this article takes the case of the East Japan Soil Becquerel Measurement Project to illuminate how temporalities are contested and reconstructed in the production and representation of data on soil contamination and how the political order of "post-Fukushima" Japanese society is discussed. As Sharma (2014) aptly pointed out:

> Temporalities…exist in a grid of temporal power relations. The term *temporal*…does not imply a transcendent sense of time or the time of history…The temporal is not a general sense of time particular to an epoch of history but a specific experience of time that is structured in specific political and economic contexts. (p. 9; emphasis in original)

Given these theoretical frameworks, the research questions for the article can be put as follows: How did MDS create its own database of soil contamination as a resource for making its temporality of the disaster? What kind of future did MDS envisage by using its resulting database and digital media? While many scholars have examined MDS as a case of a Japanese citizen science initiative (e.g., Kenens et al., 2020; Kiyohara, 2017), this study focuses on analyzing MDS as a kind of citizen science project for promoting its temporality of the disaster in map form.

To address the research questions, this article draws on Rose's (2016) discourse analysis I as a method. By discourse analysis I, Rose (2016), a professor of human geography, referred to the concept of discourse as "articulated through various kinds of visual images and verbal texts" (p. 192); in doing so, she pointedly designated images and texts themselves, their social production, and their effects as the objects of study for addressing knowledge and power.

Undoubtedly, it would be ideal to examine all the elements of MDS's radiation map of the future, but because of space constraints, the rest of the section focuses on MDS's radiation map of the future itself as images and texts and its social production as the objects of research to address the research questions. Drawing on discourse analysis I, this study examines how a particular discourse on the future temporality of the disaster, articulated through MDS's radiation map of the future, was created and structured and how it produced a scientific discourse as a rhetorical resource for envisaging the future. In doing so, this research investigates a wide variety of texts and documents—including books on MDS and other citizen science initiatives, MDS's map-books, MDS's websites and blogs, and leaflets by MDS members, among others—from 2011 to 2021.

To examine the social production of discourse, this study begins by investigating the trajectory of MDS and shows how MDS developed its data-making strategy and engaged in the East Japan Soil Becquerel Measurement Project. Like any other kind of citizen science, temporal citizen science should not be seen as static; it can be illuminated and identified through an analysis of its trajectories. With the framework of temporal citizen science, the next section moves back in time to illuminate MDS's emergence and then returns to the present because, as many scholars of infrastructure studies have aptly pointed out, understanding infrastructures requires investigating their historical development. Then, it examines MDS's radiation map of the future as the resulting product of its participatory citizen science practices through the use of digital media against the institutionalized temporalities of the Japanese state. In doing so, this study illuminates how MDS intervened in the temporalities of the Fukushima disaster through the lens of temporal citizen science.

The Minna-No Data Site and Its Data Making

To illustrate how MDS constructed its data and database on soil contamination, this section takes a brief detour through an analysis of its prehistory, which illustrates the normative stakes associated with MDS's strategies of data making. MDS has a long history extending beyond 2012, when it claimed it was established in Tokyo (Abe, 2017). The origin of MDS can be traced back to the kickoff meeting of Kodomotachi o hōshano kara mamorukai or the National Parent Network to Protect Children from Radiation (NPNPCR) in July 2011. To ensure the health and safety of children, numerous citizens across the country gathered in Tokyo and created various grassroots projects to measure radioactive contamination independently. One of these projects is particularly noteworthy for this study because the project ultimately provided institutional and cultural resources for MDS. The project was ambitious: to establish one hundred grassroots radioactivity-measuring stations with a particular focus on food safety around the country, thereby preventing unnecessary radiation exposure among children in Japan (e.g., Kimura, 2016; Sternsdorff-Cisterna, 2019). More specifically, the primary objective of the project was to understand the contamination levels of everyday foods to promote the safety of children who were reportedly sensitive to the health effects of a radiation dose. More than anything else, each food item had to be measured as accurately as possible. NPNPCR successfully achieved the goal within a short period (Kodomotachi o hōshano kara mamoru zenkoku netto wāku, 2012), but the network had one crucial problem: The generated data were not comparable between the stations. Indeed, each radiation-measuring station invented and developed its measurement method and data representation format, making it impossible to effectively compare heterogeneous data in the digital age.

Despite—or perhaps because of—the problem, MDS was established to ensure effective comparative analysis of different data on food contamination around the country. In 2012, a Nagoya-based citizens' radiation-measuring station led by professional scientists proposed the idea of a single grassroots standardized database on food contamination, leading to the establishment of MDS (Minna-no Data Site, n.d.-a). The objectives of MDS (Minna-no Data Site, n.d.-a) were as follows: "(1) To bring together citizens' abilities and knowledge to ensure that radioactivity data are not concealed: (2) To obtain factual knowledge by accumulating as much accurate and independent data as possible: (3) To provide comprehensive and user-friendly information" (para. 10). Rather than positioning itself as a value-free citizen science project, MDS publicly made its norms and values transparent by articulating these objectives. That is, its primary objective was to produce comprehensive, user-friendly information that could be used in prosecuting the cover-up of radiation data. Therefore, the most important issue MDS focused on was accuracy and independence, not the quantity of data. By defining the potential concealment of data as a legitimate problem and choosing the accuracy and independence of data as a fundamental rhetorical resource for making a scientific claim, MDS standardized its measurement and data representation methods so that its intended audiences could use its database effectively (Minna-no Data Site, 2018).

MDS initially focused on building a standardized grassroots database of food samples, but its focus gradually shifted to soil contamination, partly because the levels of internal radiation exposure were not considered a major problem, according to the actual data measured by the government and other grassroots organizations, such as Greenpeace (e.g., Abe, 2015). More importantly, MDS problematized the lack of information on soil contamination in East Japan. While the Japanese state surveyed the levels of soil contamination in some locations within Fukushima Prefecture, no comprehensive survey of soil contamination was conducted beyond the border of the prefecture. Instead, the Japanese state and its affiliated institutions, such as the Japan Atomic Energy Agency, calculated the estimated level of soil contamination through an airborne radiation monitoring system. However, neither the Japanese state nor other municipal governmental agencies directly surveyed soil samples from East Japan (Minna-no Data Site, 2018). Initially, the Nagoya-based station and Save Child Iwate, a then-MDS-affiliated organization in Iwate Prefecture, requested that the Iwate Prefectural government survey soil contamination in the prefecture; however, the municipal government answered that it was not necessary to do so because the Japanese state considered it sufficient to estimate the level of soil contamination through airborne radiation monitoring activities (Ōnuma & Yoshihara, 2018). Therefore, the Japanese state and municipal governments relied exclusively on the results of the airborne survey to make knowledge claims about soil contamination in East Japan while dismissing the environmental knowledge gained through direct soil samplings.

In response, MDS defined soil contamination in East Japan as a major issue to be revealed and launched a new project called the Higashi Ninon Dojō Bekureru Sokutei Project or the East Japan Soil Becquerel Measurement Project in 2014. In the project, multiple volunteers, most of whom were affiliated with MDS, collected soil from the environment and sent the collected soil to nearby MDS-affiliated radiation-measuring stations, where other volunteers measured the level of soil contamination in a standardized way and inputted the resulting data into MDS's newly established database on soil contamination.

In doing so, MDS invented a mechanism that allowed many ordinary citizens to participate in the data collection process while ensuring the data's accuracy and independence. As in Ottinger's (2010) study of citizen science with bucket air samplers, for instance, MDS tactically developed a data collection method by standardizing a one-liter carton as the data sampler. The one-litter carton, such as a milk carton, was not only widely accessible at grocery stores and supermarkets across the country but was also made of tearproof and environmentally friendly paper. As such, it was easy to carry around for data collection, allowing different volunteers to efficiently collect the expected amount of soil necessary for the project (Minna-no Data Site, n.d.-b).

Significantly, the data collection method goes beyond choosing the data sampler, partly because of the characteristics of imperceptible radioactive materials. Because the materials were distributed in a patchy fashion, it was important to standardize where and how a soil sample could be taken with the one-liter cartons. As such, MDS detailed a soil collection method on its website in clearly understandable terms and issued a reader-friendly cartoon booklet, entitled *Higashi Nihon Dojō Bekureru Sokutei Project Toranomaki* or *The Guidebook for the East Japan Soil Becquerel Measurement Project*, for prospective volunteering audiences (Minna-no Data Site, n.d.-b). Accordingly, MDS made its data collection method publicly available to wider audiences, including those who were not affiliated with MDS. Given that it was difficult for MDS members to demonstrate how they actually collected soil samples for their intended audiences, it was crucial to provide information on the data collection method to validate the accuracy of the individual data, at least rhetorically (Abe, 2020b).

More notably, MDS constructed its data collection method to fit the state's method (Minna-no Data Site, n.d.-b). In the wake of the disaster, many citizens focused on discovering hot spots where the radiation level was significantly higher than that of neighboring areas (Abe, 2015). In 2013, however, the Japanese state and the Ministry of Environment (MOE) in particular issued a guideline entitled *The Guideline for Measuring Radiation and Confirming the Effects of Decontamination*, emphasizing the need to differentiate hot spots from other areas for the sake of effective decontamination practices. Accordingly, the guideline maintained that it was necessary to avoid measuring radiation in "areas where hotspots are presumably included" (Kankyōshō, 2013, p. 6). In doing so, the Japanese state selectively defined "good" measurement data by excluding radioactivity measurement data taken at hot spots to implement an effective decontamination practice.

Rather than resisting the MOE's framing of good data, MDS similarly emphasized the need to *avoid* measuring hot spots to build a good database on soil contamination (Minna-no Data Site, n.d.-b). In *The Guidebook for the East Japan Soil Becquerel Measurement Project*, MDS redefined a microhotspot as "a singular point" and noted that "if singular points are displayed on the map, it will look as if its high values represented those of the entire area" (Minna-no Data Site, n.d.-b, p. 6). MDS thus clearly highlighted the fact that it adheres to the state's guidelines for data collection practice, making sure, at least rhetorically, that the validity of its collected data would be ensured from the perspective of the state's risk management. To exercise quality control over the collected data, key MDS volunteers not only held more than one hundred workshops about this data collection method for prospective volunteers but also used a self-made radiation source to enhance the quality control of the measurement devices of each MDS-affiliated radiation-measuring station around the country (e.g., Minna-no Data Site, 2018). Accordingly, MDS framed soil contamination as an environmental problem to be revealed and tactically chose how its data could be seen as both accurate and independent, even from the perspective of the Japanese state.

With the objectives and data production practices described above, MDS collected more than 3,400 data points on soil contamination in 17 prefectures from October 2014 to September 2017 through the participation of 4,000 volunteers (Minna-no Data Site, 2019). With the collected data, MDS developed its online database on soil contamination as a knowledge infrastructure and later created its online map of soil contamination in East Japan. The next section illuminates how MDS envisaged and represented risks in the future through the use of its map.

Reimagining the Temporalities of the Fukushima Disaster

In September 2013, in a bid to host the 2020 Summer Olympics and Paralympics, Shinzo Abe, then Prime Minister of Japan, asserted that the Fukushima situation was "under control" (e.g., Linden, 2013). Subsequently, the Japanese state gradually lifted evacuation orders under the condition that the annual cumulative dose, which was estimated from the air dose rate, was below the state's post-disaster standard of 20 milliSieverts (mSv) per year. The Japanese state thus redefined the spatial boundaries of the Fukushima disaster and reframed its temporality.

Under the circumstances, MDS used a crowdsourcing system and published a map-book based on its collected data and online map on November 13, 2018. The title of the book can be translated as *Illustration 17 Prefectures Radiation Measurement Map plus Commentary.* The 200-page map-book, as a "culmination of what MDS has engaged to measure for the past six years" (Minna-no Data Site, 2018, p. 2), not only visualizes environmental radiation levels but also provides MDS's comprehensive explanations of food and soil contamination, not leaving its readers to judge the consequences of the disaster with the collected data alone (Minna-no Data Site, 2018).

To show the levels of soil contamination in map form, MDS calculated and estimated the levels of soil contamination in March 2011 by using soil samples collected from October 2014 to September 2017 as part of the East Japan Soil Becquerel Measurement Project. In doing so, MDS processed and categorized its collected data on soil contamination into 12 colored layers, allowing its audience to see the levels of soil contamination in East Japan at a glance. More significantly, MDS's composition of individual data and 12 colored layers reflected how countries, such as Belarus and Ukraine framed the consequences of the Chernobyl nuclear disaster (Abe, 2017; Baba & Omatsu, 2016; Nasvit, 1998). For example, MDS described contamination levels of more than 600 becquerels per kilogram and below 1 mSv per year as "residential zones with some kind of social security or benefit under Chernobyl law" (Minna-no Data Site, 2018, p. 8) and colored levels of contamination as orange, accordingly. In fact, one of Ukraine's Chernobyl Laws of 1991 not only framed contaminated areas as those where a resident's exposure dose because of the consequences of the Chernobyl disaster exceeded 1 mSv per year but also guaranteed the right of evacuation for residents in the designated contaminated areas (Baba & Omatsu, 2016).

To better understand MDS's data representation practice, it is useful to discuss how the Japanese state categorized its data on soil contamination in its Extension Site of Distribution Map for Radiation Dose, etc. (Mombu kagakushō, n.d.). In the most comprehensive radiation map of the Japanese state, the Japanese state categorized its data on soil contamination into nine colored layers. Most notably, the Japanese state set the minimal measurement value at 10,000 becquerels per meter, shown in light brown on the map (Mombu kagakushō, n.d.), marking the knowledge of soil contamination on those below 10,000 becquerels per meter as "nonknowledge" (Jasanoff, 2017). In response, MDS set the minimal value at 50 becquerels per kilogram on the map, allowing its users to see more detailed and nuanced information on soil contamination in East Japan at a glance (Minna-no Data Site, 2018) and providing an alternative way of knowing soil contamination after Fukushima. In doing so, MDS provided a communication resource for assessing the rationality of the state's knowledge claim on soil contamination.

More significantly, MDS published a radiation map of the future or a "100 years from now" prediction map showing the estimated radioactive decay in the environment in East Japan (Figure 1). In what follows, this section investigates how MDS represented future radioactive decay on the map and discusses how it made its temporality of the disaster by doing so.

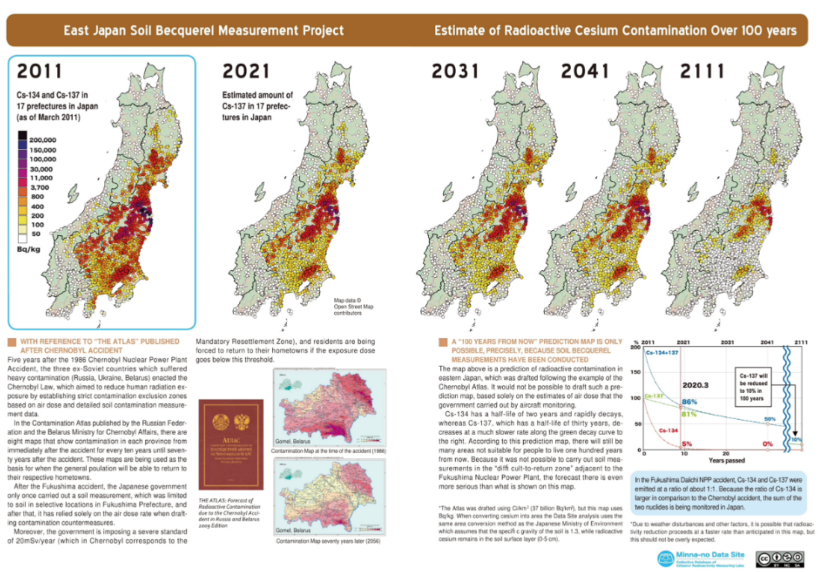

Figure 1. Estimate of radioactive cesium contamination over 100 years.
Note. From East Japan Soil Becquerel Measurement Project Estimate of Radioactive Cesium Contamination over 100 Years (Minna-no Data Site, 2020). CC By-NC-SA.

Most strikingly, the "100 years from now" prediction map shows four different maps of environmental radiation decay for the 17 prefectures in East Japan (Kenens, Van Oudheusden, Van Hoyweghen, & Mizushima, 2021). The representation of the prediction map was based on MDS's calculation of the combined amount of cesium-134 and cesium-137 isotopes back in 2011, allowing MDS to estimate the levels of soil contamination 10 years, 20 years, 30 years, and 100 years after the Fukushima disaster. Given that the half-lives of the cesium-134 and cesium-137 isotopes are approximately two years and 30 years, respectively, the prediction map focuses on visualizing the extent to which cesium-137 will decay by 2021, 2031, 2041, and 2111. MDS excluded the cesium-134 isotope as a unit of analysis of soil contamination in the future because the Belarusian government did so when it issued a radiation contamination map five years after the Chernobyl nuclear disaster (Minna-no Data Site, 2018). As such, MDS's data selection and visualization practices on the map were based on the Belarusian government's response to the Chernobyl nuclear accident.

With its categorization of soil contamination levels in light of the Chernobyl Law, MDS's "100 years from now" prediction map allows users to particularly see the levels of soil contamination in the future. For example, the prediction map shows that even in 2111, one hundred years after the Fukushima disaster, there will be spots suggesting that levels of soil contamination are 400–800 becquerels per kilogram in Chiba Prefecture, next to Tokyo. Given that the level of 100 becquerels per kilogram is considered low-level radioactive waste in Japanese law (e.g., Ishimaru, 2016), the prediction map allows its users to see future risks outside Fukushima Prefecture. While the radiation map of the future can be seen or even used as a political resource for disrupting the state's recovery practices for decades to come, it is important to note that the levels of soil contamination shown on the map are based on the assumption that there will be no nuclear accidents in Japan or elsewhere in the next 100 years. Therefore, the radiation map of the future can also be seen to exemplify our hope.

While MDS created an alternative way of seeing the temporality of the disaster in the future, the Japanese state's map does not allow its users to see the estimated levels of soil contamination in the future. Indeed, the Extension Site of Distribution Map for Radiation Dose, etc. allows its users to see the levels of soil contamination in the past (specifically in the first half of 2014, the second half of 2014, October 2015, October 2016, October 2017, October 2018, October 2019, October 2020, and October 2021 as of this writing; Mombu kagakushō, n.d.), enabling users to see radioactive decay of the past years. This is particularly significant to Beck's (1992) view of the future and its power to determine the present. While Beck (1992) pointed out that, in a risk society, the center of risk consciousness does not lie in the past but in the future, the Japanese state's radiation map focused on showing the levels of soil contamination in the past through digital media, framing soil contamination as a matter of the past and dismissing the issue of the future. In other words, the Japanese state's radiation map foregrounded the levels of soil contamination as scientific knowledge, ignoring the estimated levels of soil contamination in the future as "nonknowledge" (Jasanoff, 2017).

Understandably, the Japanese state would have difficulty making the estimated levels of soil contamination available to the public partly because, as Beck (1992) pointed out, all information on future soil contamination is invented and fictive, even if it is based on calculation. In response, MDS generated its data on soil contamination and allowed its users to see the estimated levels of soil contamination in the future through its calculation of radioactive decay and its effective use of digital media. From Beck's (1992) perspective, MDS effectively represented the disaster's temporality and envisaged the future using its collected data and digital media, allowing its users to perceive future risks. In doing so, MDS generated a civic epistemology by which citizens deployed science-based knowledge claims about the present or long now as the post-Fukushima period collectively. This is alternative knowledge making in the digital age. MDS collected and analyzed soil samples by itself and created its database as a knowledge infrastructure. By using the database, it effectively calculated the radioactive decay of soil contamination and employed digital media to represent the estimated levels of future soil contamination in map form. As such, MDS's knowledge-making practice epitomizes what temporal citizen science looks like.

All these temporal citizen science practices might have been radically different without digital technologies. While it might have been technically possible to create the prediction map without digital media, MDS used OpenStreetMaps and promptly transformed the collected data into data on future radioactive decays. In the process, digital technologies allowed MDS to expand the scale and scope of its prompt interventions in the temporality of the Fukushima disaster in Japan. While many scholars have focused on the role of digital technology in the production of data (e.g., Wynn, 2017), this study shows that digital technologies are similarly one of the key components of the production of temporalities through the lens of temporal citizen science.

This section shows how MDS engaged in creating a timely intervention in the temporality politics of the Fukushima disaster using digital media. While the Japanese state redefined the space of the disaster and reframed the temporality of the disaster accordingly, MDS used digital technology to process the collected data as a resource for representing the levels of future soil contamination in East Japan. Its citizen science practices went beyond concepts like geographic citizen science precisely because its primary focus was on reimagining the temporality of the Fukushima disaster secured by the Japanese government. This does not necessarily mean that digital technologies caused temporal citizen science, but it was MDS that capitalized on digital technology and its collected data to shape temporal citizen science practices.

Conclusion

In 2021, it is no longer common to see ordinary people measure environmental radiation for their health and safety. Accordingly, it is reasonable to assume that the role of citizen science is essentially temporal or transient in disaster recovery; that is, citizen science projects might work *for the time being* until most people become convinced that their health and safety are ensured in their surroundings. Put differently, almost nothing socially meaningful will be left for citizen science projects years after the Fukushima disaster. In response, this article uses MDS as a case study to discuss the role of citizen science in disaster recovery and makes a counterargument against this assumption.

This study shows that MDS was actively engaged in highlighting the politics of the temporalities of disasters in the digital era. While the Japanese state set a post-disaster standard for lifting its evacuation order and defined post-Fukushima Japanese society in terms of "recovery," MDS tactically used digital media and published a radiation map of the future to disrupt the state's temporality of the disaster. Just as Beck (1992) refers to the characteristics of contemporary risk consciousness, MDS represents future risks to engage in political intervention in what constitutes “post-Fukushima” currently. While many citizen science researchers have focused on the role of citizen science in reconfiguring the spatial scale of disasters through the lens of geographic citizen science, this finding adds the dimension of both time and digital media to the discussion, which focuses mainly on the dimensions of space and geography.

To make sense of citizen science in the digital era, it is necessary to note the temporal resources that citizen science practitioners deploy for the public good. The concept of temporal citizen science offers insight into the inequality of the temporalities of the nuclear disaster, although it is important to mention that the findings of temporal citizen science, just as those of geographic citizen science, could be a resource for creating baseless rumors and stigmatizing Fukushima and elsewhere. Temporalities of nuclear disasters are essentially contested and radically different from those of natural disasters, such as earthquakes, which makes it necessary to theorize temporal citizen science as a framework for better understanding the role of citizen science practitioners in the politics of the nuclear disaster temporalities in the digital age.

This study is based solely on a discourse analysis of various texts, including MDS’s website, its map-book, and Japanese media sources. To better understand MDS’s temporal citizen science practices, it is perhaps necessary to interview audience members to obtain their views of MDS’s database and map-book. This should be a direction for future scholars to take, but this study has demonstrated that citizen science plays a constitutive role in shaping the temporalities of the disaster. Citizen science might be temporal in terms of its spatial data-making practice, but it could still be persistent in creating alternative temporalities. This study thus indicates the need to pay more attention to the temporal aspect of the disaster in which citizen science practitioners can intervene, even after the state’s institution has increasingly defined the spatial scale of the disaster. In doing so, this foregrounds the role of citizen science in shaping the temporalities of contemporary society in Japan and helps reimagine citizen science in the digital age.

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