Comprehensive data on ionising radiation from Fukushima Daiichi nuclear power plant in the town of Miharu, Fukushima prefecture: The Misho Project

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Comprehensive data on ionising radiation from Fukushima Daiichi nuclear power plant in the town of Miharu, Fukushima prefecture: The Misho Project

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Received 15 April 2014, revised 11 July 2014
Accepted for publication 15 July 2014
Published 14 August 2014

Abstract
Data related to radioactivity released from the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident on 15 March 2011 gathered by residents of Miharu, Fukushima Prefecture, and by Tohoku University are presented. These data sets consist of (1) the earliest radiation monitoring by a Geiger counter in the town, (2) ratios of radioactivity between ¹³²Te and ¹³⁷Cs for a wide area between Fukushima and Tokyo, (3) radiation measurement of soil samples collected from 18 school grounds, and (4) external radiation exposure of 1400 students using OSL badges. By combining and analysing these various data sets, a curve for the cumulative total external exposure as a function of time, with 16:00 h on 15 March 2011 being time zero, is obtained. The average cumulative external dosage is estimated to be 10 mSv
The town of Miharu is located 45 km directly to the west of Fukushima Daiichi Nuclear Power Plant (FDNPP) in Fukushima Prefecture in Japan (figure 1). In the chaos of the Eastern Japan Great Earthquake of 11 March 2011, and the unprecedented nuclear power accident that followed at the tsunami-stricken FDNPP, Miharu, with a population of approximately 18 000, ended up as the sole municipality to administer iodine tablets to its residents. At the time of the accident, Miharu had no knowledge of using this kind of tablet, nor did they know of their existence. However, the value of these tablets had been brought to the attention of Miharu’s civil government officials. Miharu became the host to about 2000 evacuating residents from within the 20 km radius zone of FDNPP; these evacuees were given the iodine tablets at the place of their evacuation. Two of the authors, H and K Sakuma, initiated a recording of radiation levels with their own Geiger counter about two hours after the hydrogen explosion at the No. 1 reactor of FDNPP, which was at 15:36 h (JST) on 12 March 2011. These measurements have been continued since this time, and the first three months constitute the first set of data presented in this article. These recorded data clearly document the arrival and passing of the radioactive plume on 15 March and demonstrate that there was no major fallout from FDNPP thereafter. It is indeed fortunate that this civil measurement was conducted in the very town where the stable iodine was administered, so that its timing and effect could be quantitatively assessed, as is presented in the current article.

Independently, authors from Tohoku University (hereafter referred to as Tohoku) began collecting soil samples, mostly along the major expressways within a 200 km radius centred around FDNPP starting on 27 March. The radioactivities of these samples were measured using high purity germanium (HPGe) detectors. The results of these measurements constitute the second data set.

On 14 May 2011, at the request of Miharu Municipal Government (hereafter referred to simply as Miharu), a group of volunteers made up of researchers from Tohoku, whose expertise includes radiation detection, assisted and advised the town officials in collecting topsoil samples from all 18 kindergarten, primary and middle schools in the municipality. Measurements of radioactivity of 90 samples collected were conducted at Tohoku for 131I and 134,137Cs. These data comprises the third data set in the present article.

In order to promote and encourage these grass roots efforts by the residents of Miharu, the authors from Tohoku and Miharu teamed up and established The Misho Project (hereafter referred to as Misho) on 20 June 2011 at the Miharu office. Top priority was placed on comprehending and monitoring the levels of radiation exposure of children, external as well as internal, and on creating appropriate measures to protect individuals from exposure to radiation. With this goal, on 14 July 2011 Misho distributed optically stimulated luminescence
(OSL) badges to any students (between 6 and 15 years of age) of the more than 1400 studying under the compulsory education system that requested them. Miharu was one of the first local governments to start monitoring and recording the external radiation exposure at individual levels in Fukushima. The organised school-wide monitoring of students will be continued as long as the students are in the Japanese compulsory education system (six years in primary and three years in middle school). The fourth data set consists of readings taken from the OSL badges, which had already been conducted eight times up to the time of the writing of this article. Simultaneously, the Board of Education in Miharu twice conducted a whole body counter (WBC) screening for internal radiation exposure of nearly 1400 primary and middle school children between November 2011 and February 2012 and between September and November 2012. The analysis of these data has already been presented in [1] and will not be discussed here.

The present paper is organised as follows. Section 2 describes Miharu’s earliest measurement using a Geiger counter in Miharu and discusses the timing of the Miharu advisory for the ingestion of iodine tablets. Section 3 presents ratios of radioactivity among major radionuclides, which are extracted from topsoil samples collected in a wide area (up to ~200 km radius from FDNPP) of eastern Japan. Then these ratios are compared to existing studies. In section 4, the results of radioactivity measurement including $^{131}$I on the topsoils of school grounds in Miharu are presented. Section 5 presents the results of individual measurements of external exposure to radiation using the OSL badges and gives an estimate of the averaged cumulative dose combining all the data we have presented in this paper.

Each section is dedicated to a particular data set and is more or less self-contained. Moreover, sections are chronologically ordered from the earliest to the most recent. This way of organising the paper is intended to document the communal approach that the residents of Miharu and scientists, with little experience in environmental radiation, took to respond to the crisis. We have experienced first hand the importance of collectively protecting ourselves from radiation when accurate data and scientific consensus were absent. Accordingly, the Misho directive states that the project must remain as independent and neutral as possible, and be as scientific as it practically can be—see appendix C for the statement of purpose of The Misho Project. The last phrase, *as scientific as it practically can be*, implies that Misho puts an emphasis on the quality of life of the participating residents rather than the rigor required.
of any scientific analysis. Having stated this, we still believe that the data sets presented here will add invaluable information to the on-going worldwide efforts to understand what really happened and to assess the impact of the FDNPP accident on affected residents.

2. The earliest radiation measurement by a Geiger counter

2.1. Method and data

In Miharu, the earliest monitoring of radiation levels was started by two of the present authors (H Sakuma, a retired middle school teacher, and his wife, Kazuko) using an R-DAN (Tau Giken Co. Ltd, RD-0806) Geiger counter [3]. The detector had been located in the living room of their residence since 1990, four years after the Chernobyl accident in 1986. The integration time is 1 min. The monitoring and recording of the readings (written down by hand in a systematic way) was started at 17:13 h on 12 March 2011 following the explosion in the No. 1 reactor of FDNPP at 15:36 h on the same day. One measurement consists of ten sets of reading off the number (CPM) at every minute. Figure 2 shows CPM as a function of time from 12 March to 30 June 2011, over two and a half months. The inset vividly captures the passing of a radioactive plume over this area with a minute accuracy on 15 March. At around 6:00 h of that morning, explosions were heard in Reactor No. 2 and observed in Reactor No. 4. At the time of the plume passing over, Miharu and H and K Sakuma recalled observing sleet in this region. The reading is missing between 14:52 h and 16:00 h. The Sakumas recalled a great sense of relief when there was an abrupt drop in the count rate, and they took a break during that time after manually recording the radiation levels with their Geiger counter non-stop. The record also clearly documents the absence of fallout after 15 March.

On 15 March, an independent survey was conducted along the major expressways northeast of Tokyo, as reported in [4]. The highest radiation levels were recorded at 15:23 h, 1.3 km

Figure 2. Counts per minute plot recorded by R-DAN. The recording started at 17:13 h (JST) on 12 March 2011.
east of the Koriyama Higashi Interchange on the Banetsu Expressway, which is only about 5 km away from the residence of Sakuma. At the same time, radionuclides were identified by gamma-ray spectrum using a LaBr3 scintillation spectrometer. Because the H & K Sakuma measurements were conducted at the same location over a period of time, a decay curve can be obtained assuming radioactive nuclei identified in [4], namely, $^{132}$Te, $^{131}$I, $^{134,136,137}$Cs, plus a constant environmental background radiation level. The effect of shielding from γ rays on CPM when the Geiger counter is located indoors must be considered, but is neglected in the present analysis. A schematic diagram of the Sakumas’ residence and the position of the Geiger counter is given in appendix A, figure A1.

### Table 1. Relative counting rates at 16:00 h on 15 March 2011 extracted from fitting of the decay curve in figure 3.

| Nuclide      | Half-life | %  |
|--------------|-----------|----|
| $^{132}$Te/$^{132}$I | 3.2 d/2.3 h | 68 |
| $^{131}$I   | 8.02 d    | 11 |
| $^{134}$Cs  | 2 yr      | 11 |
| $^{136}$Cs  | 13 d      | 4  |
| $^{137}$Cs  | 30 yr     | 4  |
| Natural     |           | 2  |

Figure 3. A decay curve fitted with $^{132}$Te/$^{132}$I, $^{131}$I, $^{134,136,137}$Cs, and a constant background. The fit is performed from 16:00 h on 15 March onward. Transient equilibrium [2] is assumed between $^{132}$Te and $^{132}$I.

2.2. Results and discussion

The result is presented in figure 3 for the period between 16:00 h on 15 March and 30 June 2011. Table 1 summarises the compositions of the decay curve. In Miharu, the residents first became exposed to the radiation at around 13:30 h on 15 March. For the following week, a dominant source of radiation is the decay of $^{132}$Te and its daughter $^{132}$I, which is followed by $^{131}$I. As will be discussed in the following section, from the early measurements of the soil...
samples, the intensities of radioactivity is strongly correlated among $^{132}\text{Te}$ and $^{134,136,137}\text{Cs}$, while that of $^{131}\text{I}$ lacks such a correlation.

At the early stage of the accident, inhalation of radioactive iodine (and thus exposure to radiation internally) is the central issue. Because of the paucity of information on the spread of $^{131}\text{I}$, estimating the levels of internal exposure is an area of high uncertainty. However, the present data show that the early radiation exposure results from $^{132}\text{Te}$ and its decay daughter $^{132}\text{I}$, and spread of these radionuclides can be accurately identified based on the correlation with $^{134}\text{Cs}$ and $^{137}\text{Cs}$. Indeed, the spread of both radionuclides was measured systematically by the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT) in collaboration with the Japanese universities and research institutes nationwide [5, 6], in which the authors from Tohoku also took part. In fact, a radiation survey of 18 school grounds in Miharu, which is discussed in section 4, followed closely the prescribed procedures of the MEXT wide area mesh survey [6].

2.3. On the timing of the Miharu advisory

Although the present data set cannot itself provide information on the amount of $^{131}\text{I}$ intake, Miharu residents under 40 years of age were advised to take stable iodine tablets immediately at 13:00 h on 15 March. According to WHO guidelines for iodine prophylaxis following nuclear accidents [7], the averted dose from inhaling radioactive $^{131}\text{I}$ for 4 h is 100% if stable iodine tablets are administered prior to or at the beginning of the intake. At that time, the Fukushima Prefectural Government and some Japanese mass media were critical of the initiative taken by Miharu. Furthermore, an official review and evaluation of the process was not made by the Japanese government or by Fukushima Prefecture. As to whether the ingestion has any health benefits in the course of the FDNPP accident cannot be accessed from the present data alone. However, from a standpoint of radiation safety and the protection of residents, the Miharu advisory was appropriate and timely when almost no information was available to the public regarding the spread of radioactivity, let alone the state of the troubled reactors at FDNPP on 15 March. In addition, it is noted that no side effects have been confirmed by those who took the iodine tablets. It is hoped that the present study contributes to establishing better policies and procedures for administering stable iodine in response to similar accidents in the future.

3. Measurement of $^{132}\text{Te}/^{137}\text{Cs}$ from topsoil samples

3.1. Motivation and background

The importance of taking $^{132}\text{Te}$ and $^{132}\text{I}$ into account in total radiation exposure in the early days of the accident has been recognised and discussed in [8, 9]. Our data further support these claims. In [8], data were taken from 17 to 19 March 2011 using $\gamma$-ray spectrometry with a portable Ge detector; however, the study was undertaken at the fixed location of Fukushima City. On the other hand, the $^{132}\text{Te}/^{129m}\text{Te}$ ratio was obtained in [9], and this ratio was used to infer the spread of $^{132}\text{Te}$ based on the amount of $^{129m}\text{Te}$ (half-life: 33.6 d) measured in soil samples of the wide-area survey. A direct measurement of $^{132}\text{Te}/^{137}\text{Cs}$ and its dependence on locations is highly desirable, since the spread of $^{137}\text{Cs}$ has been well documented owing to its long life-time of 30 years.

Incidentally, the authors from Tohoku voluntarily collected topsoil samples along major expressways, namely, Tohoku, Ban-etsu, and Jyoban, which cover a wide area south and west of FDNPP, as well as in Fukushima City and the village of Iitate, Fukushima Prefecture.
The samplings were conducted between 26 March and 30 April 2011. The sites of the samples collected are indicated in figure 4. \(\gamma\)-ray spectroscopy of these samples with an HPGe detector was performed. Details of the measurements will be described in the next section. Since the authors from Tohoku have very little experience in environmental radiation measurements, procedures for collecting and preparing soil samples were not unified at that time. For this reason, values for the absolute radioactivity do not have much scientific significance. Nevertheless, relative intensities between airborne radionuclides are less affected by sampling procedures and can be compared between the samples. In addition, the measurements were made using the same setup, and thus the systematic error is reduced.

3.2. Results and discussion

An energy spectrum of a soil sample collected at Fukushima city on 27 March and measured the next day is shown in figure 6. \(^{132}\)Te and \(^{132}\)I are clearly visible with \(^{131}\)I and the \(^{134,136,137}\)Cs isotopes. In figure 5, ratios of radioactivity between \(^{132}\)Te and \(^{134}\)Cs are plotted with \(^{134}\)Cs/\(^{137}\)Cs, \(^{136}\)Cs/\(^{134}\)Cs, \(^{131}\)I/\(^{134}\)Cs, and \(^{132}\)Te/\(^{129}\)Te. The horizontal axis is the date and time of measurement of the samples taken at locations indicated in figure 4. In table 2, the measured radioactivity ratios normalised to that of \(^{137}\)Cs are summarised. These values are compared to the values decay corrected to 16:00 h on 15 March given by a compilation study.
of [10]. In addition, Beck’s coefficients [11], which will be used for estimating a cumulative external radiation dose in section 5, are listed as well.

3.2.1 \( ^{134}\text{Cs}/^{137}\text{Cs} \). Systematically lower values of \( ^{134}\text{Cs}/^{137}\text{Cs} \) compared to the average of 0.98 can be noticed in figure 5. The earlier the time of measurement is, the smaller the ratio gets. However, this trend is absent from the \( ^{136}\text{Cs}/^{134}\text{Cs} \) plot. When the measurements were started at Tohoku on 28 March, the facility was severely damaged by the earthquake, with a limited supply of liquid nitrogen for cooling our Ge detectors. Thus, we used a Ge detector equipped with a compact pulse tube refrigerator, which runs on regular AC power. Because of the electrical noise from the power supply, our Ge detector resolution was 6.4 keV (FWHM) at the 667 keV \( \gamma \)-ray energy. (The resolution was later improved.) Therefore, the 661.7 keV and the 667.7 keV peaks from \(^{131}\text{I}\) and \(^{137}\text{Cs}\), respectively, are not clearly resolved, and the fitting of these two peaks results in the underfitting of peak counts for \(^{137}\text{Cs}\). This systematic trend disappears after \( \sim 30 \) d, which is the ten half-life time of \(^{132}\text{Te}\). Accordingly, in figure 5, radioactivities are plotted against \(^{134}\text{Cs}\) rather than \(^{137}\text{Cs}\). In [15], radioactivities (decay corrected to 15 March) of soil samples collected and measured between 15 and 30 March are reported. The weighted average is 0.89, but 0.69 is reported for the Iwaki Chuo IC sample point at which the highest \(^{132}\text{Te}/^{137}\text{Cs}\) ratio is measured. The lower \(^{134}\text{Cs}/^{137}\text{Cs}\) in this case may also result from the overfitting of the \(^{137}\text{Cs}\) due to the strong presence of \(^{132}\text{Te}\) peak.

The average \(^{134}\text{Cs}/^{137}\text{Cs}\) ratio from the present work is 0.98, with \( \sigma = 0.03 \), showing little place dependence. This value is consistent with other reported ratios: 0.90 ± 0.01 [10], 0.89 ± 0.01 [15], 0.91 [6] and 0.99 ± 0.03 [12].

3.2.2 Abnormality in \(^{132}\text{Te}/^{137}\text{Cs}\). Although not as good as the uniformity in \(^{134,136}\text{Cs}/^{137}\text{Cs}\), fluctuation in values of \(^{132}\text{Te}/^{134}\text{Cs}\) are about 20% (1\( \sigma \)) except for an abnormality observed from three samples which are collected south of FDNPP. They are from Iwaki Miwa IC (sample collected on 26 March), with \(^{132}\text{Te}/^{137}\text{Cs} = 80.6 \pm 2.1\), Yunotake PA (29 March), with 64.8 ± 3.6, and Nakoso (29 March), with 37.4 ± 2.3, all in Fukushima Prefecture. Thus, these points are excluded from averaging. Insightful data can be found in table 6 of [12]. The average \(^{132}\text{Te}/^{137}\text{Cs}\) ratio (decay corrected to 15 March) of soil samples taken at 11 locations is 7.6, with \( \sigma = 1.4 \). This compares well with our value of 6.9, with \( \sigma = 1.5 \), excluding the three locations mentioned earlier. However, the former includes two locations in Iwaki City with the ratios of 7.0 and 7.8; the soil samples at these locations were collected on 18 March. All of our samples were collected after 26 March.

Between 20 and 23 March, rainfalls were recorded in the northern Kanto region, which includes Iwaki City, sharing borders with Ibaraki Prefecture. The second major radioactive

| Nuclide | Ratio | \( \sigma \) | Reference [10] | Beck |
|---------|-------|---------|---------------|------|
| \(^{132}\text{Te}\) | 6.9 | 1.5 | 7.7 ± 0.7 | 6.19 \times 10^{-4} |
| \(^{132}\text{I}\) | 9.4 | 12.0 | 15.9 ± 2.6 | 6.57 \times 10^{-3} |
| \(^{134}\text{Cs}\) | 0.98 | 0.03 | 0.90 ± 0.01 | 4.54 \times 10^{-3} |
| \(^{136}\text{Cs}\) | 0.21 | 0.02 | 0.18 ± 0.01 | 6.15 \times 10^{-4} |
| \(^{137}\text{Cs}\) | 1 | N/A | 1 | 1.66 \times 10^{-4} |
fallout is pointed out in [13 and 14] (pp 134–6). Therefore, it could be hypothesised that the abnormality in $^{132}$Te/$^{137}$Cs observed in our Iwaki-region samples is attributable to this second fallout in this region during the 20–23 March rainfall. Additional evidence can also be found in [15]. The $^{132}$Te/$^{137}$Cs of $17.4 \pm 1.0$ (decay corrected to 15 March) is recorded at Iwaki Chuo IC, where the soil sample was collected during 20–21 March, while the weighted average ratio was $8.4 \pm 0.4$ excluding Iwaki Chuo IC, Suetsugi St., and Mt Kittoya. The last two locations are in the Iwaki region; however, the $^{132}$Te/$^{137}$Cs ratio was $7.2 \pm 0.1$ and $8.3 \pm 0.1$, respectively.

More data and studies are needed to understand why in this particular region around Iwaki City the $^{132}$Te/$^{137}$Cs ratios deviate wildly from the average. In particular, measurements of soil samples collected before 19 March from this region are important. If $^{132}$Te were released after nuclear fission reactions ceased inside the reactors, the $^{132}$Te/$^{137}$Cs ratio would be independent of the time of release. Moreover, if the ratio varies from place to place like that of $^{131}$I, this results from the chemical properties of tellurium atoms. Understanding the mechanism of

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**Figure 5.** Radioactivity ratios among $^{132}$Te, $^{129m}$Te, $^{131}$I, and $^{134,136,137}$Cs corrected back to 16:00 h on 15 March. Horizontal axes are dates and times of measuring samples from collection points on the map in figure 4. Vertical axes for the $^{132}$I and $^{132}$Te plots are in a log scale. Systematically lower $^{134}$Cs/$^{137}$Cs values can be noted for samples taken at the earlier times. In those measurements, a 667.7 keV peak from $^{132}$I was comparable to that of $^{137}$Cs at 661.7 keV. Because our Ge detector suffered a poor resolution at that time, these two peaks were not resolved and peak counts at 661.7 keV for $^{137}$Cs were systematically overestimated. (See the text for details.)
concentrated deposition of $^{132}$Te only in this region serves as one of the criteria for a complete account of the accident.

4. School ground soil sample measurement

4.1. Collection of soil samples

Samples of topsoils from 18 school grounds in Miharu were collected on 14 May 2011 by Miharu staff assisted by authors (T. Koike, K. Shimada, M. Ukai, and T. Yamamoto) from Tohoku. The survey preceded the aforementioned wide-area survey by MEXT, of which procedures for collecting samples were followed with a slight variation. Topsoil of 5 cm in depth was taken in a uniform manner and each sample was put into a plastic bag. The soil was stirred well in order to make the density of radioactive fallout as uniform as possible, and thereafter the soil was transferred into a U8 polystyrene container and weighed. For one location, five points were randomly chosen within a 3 m × 3 m lot on school grounds. In total, 90 samples were collected. After this sampling of topsoils, Miharu and the Board of Education proceeded with the removal of topsoils from the school grounds.

4.2. Measurement setup and procedure

The collected samples were measured for gamma-ray spectroscopy using two HPGe detectors (ORTEC EG&G, GMX-60220-Plus-S, 60% relative efficiency to a 3in × 3in NaI scintillator) at Tohoku. A measurement setup is shown in figure 7. Since the certified reference material IAEA-444 was not available to us, we have estimated the detection efficiency at peak energies based on results of Monte Carlo simulation using Geant4. The simulated efficiency was scaled to the measured values for the 661 keV, 1172/1333 keV peak from a calibration source of $^{137}$Cs and $^{60}$Co, respectively. On average, 5 h were spent measuring each sample.

4.3. Results

A $\gamma$-ray energy spectrum of 7-C in appendix D is shown in figure 8. The spectrum was obtained on 24 May 2011, which is almost nine half-lives of $^{131}$I after the fallout on 15
March. The 364.5 keV $^{131}$I peak can still be seen, as in the inset of figure 8. The results of these measurements are tabulated in appendix D. The listed values are decay corrected back to 16 March 2011. A strong correlation in radioactivity between $^{134}$Cs and $^{137}$Cs is prominent, as plotted in figure 9 (top); the ratio of radioactivity between $^{134}$Cs and $^{137}$Cs is nearly unity, which is consistent with figure 5. In contrast, strong correlation is between $^{131}$I and those Cs isotopes is missing also from this data set, where an order of magnitude variation in the ratio exists.
5. Individual measurements of external exposure levels on residents using OSL badges

5.1. Radiation monitoring of the general public by Miharu: the Misho scheme

The necessity and urgency of monitoring the radiation levels of exposed individuals was recognised by the public relatively quickly after the accident. A pilot study monitoring individuals for radiation exposure was about to start in the town of Kawamata, Fukushima Prefecture on 21 June 2011 [16]. For the record, we have summarised first the hurdles that The Misho Project faced before the distribution of OSL badges to school children on 14 July 2011, nearly four months after the accident at FDNPP. The biggest hurdle was a legislative one. There was no legislative system nor was there a set of procedures to monitor the general public for exposure to radiation outside the radiation restricted area. Domestic agencies (companies) involved in monitoring the radiation levels of workers in the nuclear industry or research institutes (similar to those commonly used by the authors from Tohoku undertaking scientific activities in restricted areas) presented to us the following difficulties (H Komori and I Kobayashi).

- In Japan, only corporations are permitted to possess radioactive isotopes and ionising radiation emitting apparatus. Thus, there was no anticipation for the need to monitor the general public for individual radiation levels. In addition, the contents of an evaluation of an individual’s external exposure to radiation may not be comprehensible to those without a basic knowledge of radiation safety. For these reasons, radiation badges are not offered to the general public.
- The number of radiation workers in Japan is estimated to be 400000. The inventory of the badges available was only enough to carry out regular monitoring of these workers and not enough to monitor the general public at that time. The monitoring of existing clients had to be continued, and thus the distribution of radiation badges to residents was not actively considered.

Even if a service to monitor the general public for exposure to radiation were to be made available, Mihoso realised early on that regular readings of badges designed to monitor radiation levels over an extended period of several years was too costly an enterprise. On the other
hand, having children equipped with real-time dosimeters which required batteries was not an option in terms of privacy, cost and durability.

After some discussion with Nagase Landauer, Misho adopted OSL (InLight®) badges and a portable reader for them (microStar®). Using this system, the cost could be limited to purchasing one OSL badge per student and its reader, and to the expense of calibrating the reader once a year. The Board of Education personnel were trained under the supervision of I Kobayashi of Nagase Landauer. Using this method, it has now become possible to distribute OSL badges and perform, in a self-sufficient manner, the ongoing measurement, collection, recording and reporting of results to individual students, while also allowing the return of the badges for the next measurement cycle. The advantage of this system is that the OSL badges can be given to individual students for continued monitoring long after they have graduated from junior high school.

5.2. Data and analysis

Soon after the inauguration of Misho on 20 June 2011, the Miharu Board of Education asked all students of elementary and junior high schools in the municipality whether or not they
wanted to volunteer and be monitored for external exposure to radiation. As a result, 1411 students, namely about 85% of the student population, participated in this measurement and monitoring program, which was started on 14 July 2011. The zeroth reading of each OSL badge (offset) was performed just before their distribution to respective students. Since the start of the program, eight measurement cycles have been performed in over 900 d. Of the participating students, 522 of them have undergone every one of the monitoring cycles.

One badge was placed at one particular location inside the Miharu office building as a reference. Figure 10(a) shows the readings of the reference OSL badge. Days on the horizontal axis were counted from 15 March 2011. The offset value is subtracted, giving zero on the start date of the monitoring. The red curve is obtained by considering contributions only from $^{137}\text{Cs}$ and $^{134}\text{Cs}$, which is a good approximation at about 90 d after the fallout. Equation (B.11) in appendix B is used with an initial amount of $^{137}\text{Cs}$ ($N^0$), its weathering factor ($\tau^w$), and natural background as free parameters in the fitting. For the $^{137}\text{Cs}$ and $^{134}\text{Cs}$ ratio, the measured value of $1:0.98$ extracted from figure 5 is used. As a comparison, a curve with zero weathering factor is also shown. As a result, a weathering half-life of 1.39 years is obtained. It should be noted that no decontamination around the Miharu office building was carried out over the time period that this data set was taken.

![Graph](image-url)
Figure 10(b) shows a similar plot to (a). The red circles are averaged readings of the 522 students alluded to earlier. Error bars represent one standard deviation ($\sigma$). With a background before the accident, Inat, fixed to 0.5 mSv yr$^{-1}$ inside the building and without weathering factors being considered, $N_0$ is determined from the first measurement alone. Then, theoretical values using equation (B.11) for the subsequent seven measurements are calculated for each student in the subset. The averages of calculated values for each data point are shown in a black circle, with an error bar representing one $\sigma$ propagated from the first measurement. This simple procedure reproduces the measured trend well and overestimates the cumulative dose as time increases, which is on the safe side in terms of radiation protection. It should be noted that the first measurement cycle is special, because it was conducted over a month-long summer recess and thus the radiation level of the students’ residence would be better reflected. Based on this observation, the current method is applied to 1258 students to

Figure 12. Cumulative dose prediction since 15 March 2011 for the following 10 year period. The solid curve is an average of the 1258 students with dotted lines indicating the 3$\sigma$ boundaries, within which 99.7% of the sample population falls. The dot–dashed curve is a prediction based on the highest OSL reading in the first measurement cycle.

Figure 13. Average cumulative dose estimate for the first 30 d. The solid curve is the same as in figure 11 where contributions from $^{132}$Te and $^{132}$I are included, while the dotted curve is an estimate without these contributions.
determine $N_0^0$. Initially 1411 OSL badges were distributed, but 1258 (89.2%) were actually collected for the first reading within two months. An estimation curve for cumulative external dose dating back to 16:00 h on 15 March 2011, including $^{134,136,137}$Cs, $^{132}$Te, $^{132}$I, and $^{131}$I, can be obtained as shown in figure 11. The solid line is a predicted cumulative external dose for the averaged $N_0^0$ values as a function of time over 10 years. For this, the measured ratios listed in table 2 are used except for $^{131}$I/$^{137}$Cs = 20, which is the maximum ratio measured in figure 9. A natural background dose of 0.5 mSv yr$^{-1}$ is assumed. The two dashed curves represent a 3σ band within which 99.7% of the sample body falls. The dot–dashed curve is for a student with the highest OSL reading among the first time measurements. Therefore, the current study conservatively estimates that in the town of Miharu a cumulative external dosage over the 10 years is less than 22 mSv and around 10 mSv (σ = 4.2 mSv) for the majority of the population. In figure 12, a comparison of the cumulative dose for the first month following the accident is shown with and without the contributions from $^{132}$Te and $^{132}$I. As indicated in the figure, the difference amounts to ~0.1 mSv.

Finally, the correlation between the topsoil taken from school grounds and the OSL badge measurements is checked and shown in figure 14. The horizontal axis is averaged values of the $^{137}$Cs radioactivity listed in appendix D according to the seven school districts indicated in figure 13. Similarly, the vertical axis is an averaged cumulative external exposure for the first year estimated from the first OSL reading cycle. The solid line is a linear fit of the correlation. Therefore, the present data indicate that a rough estimate for an external exposure can be obtained if the spread of $^{137}$Cs is known, as in the MEXT wide area mesh survey.

6. Summary

Comprehensive data on airborne radioactivity gathered by the people of the town of Miharu, Fukushima Prefecture, following the FDNPP accident are presented. At the same time, a
grass-roots movement undertaken by residents of Miharu to measure radiation levels under the auspices of The Misho Project is documented. We have performed a self-sufficient and self-consistent analysis of these data. The data sets gathered by Misho are summarised in figure 15. As a result, we have drawn the following conclusions.

- The major radioactive fallout in Miharu occurred between 13:45 h and 15:00 h on 15 March 2011.
- No significant increase of the radiation levels after the 15 March event has been observed in Miharu.
- $^{132}$Te and its daughter $^{132}$I are the main contributors of radiation at the early stage of the accident (about 40% of the total dose for the first three days and on average an additional $\sim 0.1$ mSv to the cumulative dose).
- The advisory by Miharu at 13:00 h on 15 March, issued to residents of Miharu suggesting that they take stable iodine tablets if they were under 40 years of age, was half an hour before the arrival of the radioactive plume.
- Radioactivity ratios were obtained among $^{132,129m}$Te, $^{131}$I, and the $^{134,136,137}$Cs isotopes.
- The $^{132}$Te/$^{137}$Cs ratio is nearly constant and independent of location except for the southern region of FDNPP, around Iwaki City, Fukushima Prefecture. Evidence for the additional fallout in this region between 20 and 23 March is presented.
- A town-wide survey of individuals’ external exposure to radiation using OSL badges was undertaken and will continue to be conducted on over 1000 schoolchildren who volunteered to be subjects in the Misho Program.
- By combining all the data gathered that are complementary to one another, an estimate for the cumulative external exposure is given as 10 mSv 10 yr$^{-1}$ on average, and 22 mSv 10 yr$^{-1}$ at maximum, including the natural background contribution.
- A rough estimate of the external exposure including immediately after the accident can be given at any location if the $^{137}$Cs radioactivity is known at that location.

Figure 15. Data sets gathered by The Misho Project in relation to 10 half-lives of radionuclides discussed in the present report. A: A Geiger counter measurement by H & K Sakuma. B: Topsoil sample studies along expressways. C: Topsoil sample studies of the selected school grounds in Miharu. D: Individual measurements using OSL badges (ongoing). E, F: WBC surveys of the students of the Miharu school district, the majority of whom are participating in D.
It is our hope that these data will be scrutinised and studied by experts and specialists worldwide. At the same time, scientific consensus on the risk of being exposed to low level radiation under 100 mSv has yet to be reached internationally. Therefore, we think that it is important to persist and continue to monitor the individual residents exposed to radiation following the FDNPP accident over a ten-year period. We have demonstrated through The Misho Project one possible way that local residents, in conjunction with their local government, can monitor in a sustainable way the outcome of exposure to radiation. Moreover, we would like to illustrate the potential effectiveness of organising an independent civil network for the monitoring of radiation levels as exemplified by the authors, H and K Sakuma, and most importantly to ensure that such civil networks can be established in the future so that critical mistakes (such as the evacuation of some residents to areas of higher radiation) can be avoided.

Last, the present paper is dedicated to the children of Miharu, and to all those who have been forced to make difficult choices as to whether to stay or not to stay in the area after the accident at FDNPP. These decisions have often resulted in splitting up families and communities.

Acknowledgments

We thank John Adamson for his generous donation to The Misho Project. We would also like to thank S Kataoka and L Kamada for translating the article into Japanese and the Misho statement of purpose into English. R A O’Reilly is also thanked for his critical reading of the manuscript and his comments. J Nagao, K Ishizaki and J Nave from Microsoft Corporation are acknowledged for their ideas and advice on online data management. We are grateful to T Sato for his advice on how to fund raise for the project. Misho is supported by private donations nationwide as well as from Germany and in part by the Fukushima Prefectural Government. The authors from Tohoku are grateful to Professor Isao Tanihata of RCNP, Osaka University, for providing us with sample collecting protocols of the MEXT wide-area survey. TK and HT would also like to thank Professor Takaharu Otsuka at the University of Tokyo for his invaluable comments. Dr Hirokazu Kawamura at CYRIC, Tohoku University and Koji Miwa at Tohoku University are acknowledged for their help during the measurements of the soil samples. The authors from Tohoku gratefully acknowledge the financial support received from The Japan Association of National Universities and the Tohoku University President’s Discretionary Spending Fund. The present study meets no financial conflicts of interest.

Appendix A. Indoor location of a Geiger counter

A Geiger counter (R-DAN) is placed inside the living room of the Sakumas’ residence. Sitting on a wooden cabinet, its position is 150 cm above the ground, 120 cm away from a glass pane, and 230 cm from a roof. The roof is made of one layer of ~0.35 mm iron sheet with 50 mm fiberglass thermal insulations.

Appendix B. Estimation of external exposure based on OSL readings

A differential equation for the number of a given radionuclide \((i)\) as a function of time is given by

\[
\frac{dN_i(t)}{dr} = -\frac{1}{\tau_i} \frac{N_i}{N_{al}} - \frac{1}{\tau_{i'}} \frac{N_i}{N_{al}}
\]  

(B.1)
where \( \tau_i \) is a physical mean life time and \( 1/\sigma_i \) reflects the decrease (increase if negative) of the radionuclide due to its mobility in the environment (weathering factor). A solution, therefore, is given by

\[
N_i(t) = N^0_i e^{-t/\tau_i}
\]

where

\[
\frac{1}{\tau_i} = \frac{1}{\tau_i} + \frac{1}{\sigma_i}.
\]

The physical half-life, \( T_{1/2}^{i} \), and \( \tau_i \) are related by

\[
T_{1/2}^{i} = (\ln 2)\tau_i.
\]

The relative intensity of radioactivities among radionuclide at the time of fallout, \( (\alpha_i) \), is given by

\[
\frac{dN}{dr} \bigg|_{t=0} = \frac{N^0_i}{N^0} = \alpha_i.
\]

Since these ratios can be determined from the topsoil measurements,

\[
N^0_i = \alpha_i \tau_i T_{1/2}^{i} N^0.
\]

Cumulative external dosage (equivalent dose 1 cm depth) measured between \( t' \) and \( t'' \) (\( t' < t'' \)) by an OSL badge is given with an annual external dose from the environment, \( I_{nat} \),

\[
\Delta I(t'' - t') = I_{nat} \frac{t'' - t'}{365} = \sum_{i=1}^{N} c_i N^0_i e^{-r/\tau_i} \left(1 - e^{-(t' - t)/\tau_i}\right)
\]

where \( c_i \) is Beck’s coefficient for the \( i \)th radionuclide [11]. Equations (B.6) and (B.8) can be solved for \( N^0_i \).

Figure A1. Location of a Geiger counter in the Sakumas’ residence.
The derivation so far assumes a single decay without any radioactive decay products. This is not the case for $^{132}$Te with its daughter $^{132}$I; however, the present case meets the condition of transient equilibrium [2]. The number of $^{132}$I, $N_i$, is given by

$$N_i(t) = \frac{\tau_{Te}}{\tau_{Te} - \tau_I} N_0 \tau_I e^{-t/\tau_{Te}} \tag{B.9}$$

where $\tau_{Te}$ and $\tau_I$ are the mean lifetimes of $^{132}$Te and $^{132}$I, respectively. This approximation allows for defining an effective Beck’s coefficient for $^{132}$Te combining activity of $^{132}$I given as

$$c_{Te}' = c_{Te} + c_I \frac{\tau_{Te}}{\tau_{Te} - \tau_I}. \tag{B.10}$$

Finally, the cumulative external dose at any given time $t$ since the FDNPP accident is obtained by

$$I(t) = N_0 \sum_{i=1}^{N} c_i \tau_i (1 - e^{-t/\tau_i}) + I_{rad} \frac{t}{365 \text{ d}}. \tag{B.11}$$

**Appendix C. The Miharu Misho Project Statement of Purpose**

20 June 2011

Drafted by The Miharu Town Council, Fukushima, Japan

Endorsed by Hirokazu Tamura, Takeshi Koike (Department of Physics, Tohoku University) and Tsutomu Shinozuka (Cyclotron Radio Isotope Center, Tohoku University)

The accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) following the 11 March 2011 Eastern Japan Great Earthquake forced residents living near the nuclear plants to evacuate. Even for those residents who escaped the evacuation, many are concerned with the long term effects of radiation on their health, especially on children and pregnant women, who are more sensitive to radiation exposure. Furthermore, farmers in the Fukushima region who have been striving to ensure the safety of their produce are facing the unbearable predicament of radioactive contamination on their farmlands, which have been passed down to them through generations. Although the Japanese and Fukushima Prefectural governments have been conducting radiation measurements and have made the results public, the number of measuring spots is as yet insufficient. Thus, a more detailed map showing the extension of the radiation spread is urgently needed. On the other hand, as the information about the accident at FDNPP unfolds and the high probability of a magnitude-8-class aftershock in the near future exists, a real time radiation monitoring system desperately needs to be established.

In the meantime, the released radioactivity not only has tainted the beautiful farming villages in Fukushima, but also has blemished the hearts of Japanese citizens. Their lack of knowledge and the lack of full disclosure of information about the radioactivity have resulted in unfounded fears and have fostered discrimination towards those people and products from Fukushima Prefecture. This trend has become epidemic worldwide and has negatively affected the Japanese economy.

The Miharu Misho Project (MMP) is a grassroots movement designed to help people overcome this unprecedented crisis of national and historical magnitude. It derives its underlying concept from the Japanese word *misho*, which refers to plants raised in a certain spot from a seed, not from a transplanted young tree. A sakura (cherry tree) woodsman living in the town...
of Miharu, Fukushima (population 20,000), located 45 km west of the FDNPP, works to grow cherry trees that should continue to bloom far into the future, even up to 1000 years from now. Miharu town is nationally acclaimed for its tradition of growing and caring for a well-known 1000 year-old cherry tree. Generations of Miharu sakura woodsmen have discovered that sakura trees thrive much better and for a longer period when their seeds are sown directly and sprout live (misho) than those which are transplanted in the same place as a young tree, which is the most common practice. Compared to the method of transplanting a young tree, the misho method takes more time for the trees to bloom, producing late bloomers.

We recognise that the radiation problem that Fukushima is facing will be solved locally, with a long-term commitment of the people who are indigenous to the area. Naturally misho (indigenous roots) is our approach. MMP provides a field (the community) for the actions (the various activities) to sprout and grow. Active and direct participation by the people of Fukushima and Japan, along with the contribution of international volunteers, ‘sow the seeds on this field’ as a ‘means’ to overcome their difficulties; these ‘means’ serve as ‘ends’ in themselves. The ‘means’ and ‘the end’ is for the community to foster self-reliance and self-sufficiency in protecting their life and lands. The community vision is to be self-governed with the scientific integrity to maintain its neutrality, fairness and openness beyond various boundaries posed by institutions controlling bureaucratic, political, economic, as well as dogmatic, religious and national interests.

The people of Miharu have proudly chosen to run the MMP themselves, effectively taking it into their own hands. The monitoring of radiation levels for children and pregnant women has become the highest priority. For students younger than high school age, long-term monitoring of their exposure to radiation will be carried out throughout their compulsory school years. Wearing an optically stimulated luminescence (OSL) badge will be systematically encouraged during school hours. Individual data will be managed and kept by the Miharu Municipal Government. This program will be implemented as soon as mid-July 2011.

As its inaugural activity, the project will conduct radiation measurements of all contaminated school grounds in the town and farmlands at the request of farmers. The measurements taken by Tohoku University researchers have until now revealed that the radioactivity in the soil fluctuates greatly even within a 5 m radius area. These findings, therefore, call for further necessary measurements to be made in each household in the affected area. To this end, the project will at its commencement procure ten radiation survey counters. It will also establish a system where Miharu residents themselves can measure radiation levels in the air on demand with the help of municipal staff. In addition, a web portal will be established, to which the measurements can be reported as desired and be viewed publicly. Its usefulness will be evaluated for a large scale operation beginning with a pilot program. On top of this, pocket dosimeters will be distributed to volunteer adults (high school age or older) so that the accumulated radiation exposure will be updated on the same portal on a weekly basis. The final stage of this project aims to disseminate the monitoring scheme and system to other municipalities based on the experiences gained through this Miharu pilot project. At the same time, this project will seek support from the Fukushima Prefectural and national governments to conduct these grassroots activities, while transmitting our progress to the world. Volunteer scientists from Tohoku University will closely cooperate with Miharu by providing scientific and technical advice, in particular pertaining to radiation safety.

It is said that Japan has experienced a once in a 1000 year disaster. People in Miharu and volunteers at Tohoku University recognise this historical emergency. We, members of MMP, who have survived all of the victims of the disaster, hereby affirm and declare that our mission is to sow the seeds for another 1000 years to come in the spirit of the Miharu Sakura woodsmen, right here and right now.
Table D1. Radioactivity of 90 topsoil samples collected from school grounds in Miharu. School district numbers correspond to those indicated in figure 13.

| School district | Sample ID | $^{131}$I (kBq kg$^{-1}$) | $^{134}$Cs (kBq kg$^{-1}$) | $^{137}$Cs (kBq kg$^{-1}$) | School district | Sample ID | $^{131}$I (kBq kg$^{-1}$) | $^{134}$Cs (kBq kg$^{-1}$) | $^{137}$Cs (kBq kg$^{-1}$) |
|----------------|-----------|--------------------------|----------------------------|---------------------------|----------------|-----------|--------------------------|----------------------------|---------------------------|
| 1-A            | 3.2 ± 0.4 | 0.44 ± 0.01              | 0.45 ± 0.01                |                           | 10-A           | 16.2 ± 1.8 | 2.08 ± 0.03              | 2.35 ± 0.03                |
| 1-B            | 7.0 ± 0.8 | 1.47 ± 0.01              | 1.66 ± 0.01                |                           | 10-B           | 10.2 ± 1.0 | 0.64 ± 0.01              | 0.69 ± 0.01                |
| 1-C            | 4.7 ± 0.3 | 0.52 ± 0.01              | 0.58 ± 0.01                | 1                         | 10-C           | 9.2 ± 1.1  | 1.23 ± 0.01              | 1.33 ± 0.01                |
| 1-D            | 4.4 ± 0.4 | 0.71 ± 0.01              | 0.77 ± 0.01                |                           | 10-D           | 5.6 ± 0.7  | 0.38 ± 0.01              | 0.41 ± 0.01                |
| 1-E            | 4.8 ± 0.8 | 0.66 ± 0.01              | 0.73 ± 0.01                |                           | 10-E           | 6.2 ± 0.8  | 0.42 ± 0.01              | 0.46 ± 0.01                |
| 2-A            | 4.6 ± 0.7 | 0.73 ± 0.01              | 0.80 ± 0.01                |                           | 11-A           | 23.1 ± 2.1 | 2.99 ± 0.04              | 3.36 ± 0.03                |
| 2-B            | 4.2 ± 0.5 | 0.26 ± 0.01              | 0.29 ± 0.01                |                           | 11-B           | 7.3 ± 1.0  | 0.52 ± 0.01              | 0.58 ± 0.01                |
| 2-C            | 8.8 ± 1.1 | 0.85 ± 0.01              | 0.91 ± 0.01                | 1                         | 11-C           | 2.4 ± 0.7  | 0.18 ± 0.01              | 0.20 ± 0.01                |
| 2-D            | 3.7 ± 0.6 | 0.59 ± 0.01              | 0.65 ± 0.01                |                           | 11-D           | 19.7 ± 1.6 | 2.19 ± 0.01              | 2.39 ± 0.01                |
| 2-E            | 5.2 ± 0.5 | 0.54 ± 0.01              | 0.58 ± 0.01                |                           | 11-E           | 11.2 ± 1.7 | 1.26 ± 0.01              | 1.37 ± 0.01                |
| 3-A            | 3.8 ± 0.8 | 0.85 ± 0.02              | 0.92 ± 0.02                |                           | 12-A           | 14.2 ± 1.0 | 1.50 ± 0.02              | 1.64 ± 0.02                |
| 3-B            | 4.0 ± 0.9 | 0.37 ± 0.01              | 0.40 ± 0.01                |                           | 12-B           | 12.4 ± 1.0 | 0.93 ± 0.01              | 1.01 ± 0.01                |
| 3-C            | 4.1 ± 0.9 | 0.88 ± 0.01              | 0.96 ± 0.01                |                           | 12-C           | 4.5 ± 0.6  | 0.38 ± 0.01              | 0.42 ± 0.01                |
| 3-D            | 3.3 ± 0.7 | 0.52 ± 0.01              | 0.56 ± 0.01                |                           | 12-D           | 13.8 ± 0.9 | 1.74 ± 0.01              | 1.86 ± 0.01                |
| 3-E            | 7.8 ± 1.1 | 1.23 ± 0.01              | 1.33 ± 0.01                |                           | 12-E           | 10.9 ± 1.3 | 1.12 ± 0.01              | 1.21 ± 0.01                |
| 4-A            | 1.4 ± 0.4 | 0.58 ± 0.01              | 0.64 ± 0.01                |                           | 13-A           | 10.4 ± 1.2 | 1.74 ± 0.02              | 1.95 ± 0.02                |
| 4-B            | 4.6 ± 2.4 | 0.19 ± 0.01              | 0.21 ± 0.01                |                           | 13-B           | 7.5 ± 1.0  | 0.84 ± 0.01              | 0.93 ± 0.01                |
| 4-C            | 5.4 ± 2.1 | 0.95 ± 0.01              | 1.05 ± 0.01                |                           | 13-C           | 6.6 ± 0.8  | 0.63 ± 0.01              | 0.68 ± 0.01                |
| 4-D            | 4.1 ± 1.1 | 1.23 ± 0.01              | 1.33 ± 0.01                |                           | 13-D           | 5.9 ± 0.6  | 0.54 ± 0.01              | 0.58 ± 0.01                |
| 4-E            | 5.5 ± 1.0 | 1.22 ± 0.01              | 1.32 ± 0.01                |                           | 13-E           | 9.1 ± 1.0  | 0.83 ± 0.01              | 0.89 ± 0.01                |
| 5-A            | 4.3 ± 0.8 | 0.31 ± 0.01              | 0.34 ± 0.01                |                           | 14-A           | 4.9 ± 0.2  | 0.50 ± 0.01              | 0.56 ± 0.01                |
| 5-B            | 4.4 ± 0.6 | 0.64 ± 0.01              | 0.72 ± 0.01                |                           | 14-B           | 4.3 ± 0.5  | 0.42 ± 0.01              | 0.46 ± 0.01                |
| 5-C            | 3.3 ± 0.2 | 0.64 ± 0.01              | 0.70 ± 0.01                |                           | 14-C           | 12.3 ± 1.4 | 1.38 ± 0.01              | 1.50 ± 0.01                |
| 5-D            | 3.0 ± 0.4 | 0.28 ± 0.01              | 0.30 ± 0.01                |                           | 14-D           | 1.4 ± 0.9  | 0.28 ± 0.01              | 0.31 ± 0.01                |
| 5-E            | 1.7 ± 0.3 | 0.45 ± 0.01              | 0.51 ± 0.01                |                           | 14-E           | 2.4 ± 0.4  | 0.18 ± 0.01              | 0.20 ± 0.01                |
| 6-A            | 2.1 ± 0.7 | 0.70 ± 0.01              | 0.77 ± 0.01                |                           | 15-A           | 4.3 ± 0.7  | 0.39 ± 0.01              | 0.45 ± 0.01                |
| 6-B            | 4.8 ± 0.7 | 0.40 ± 0.01              | 0.44 ± 0.01                |                           | 15-B           | 5.0 ± 0.6  | 0.08 ± 0.01              | 0.09 ± 0.01                |
| 6-C            | 3.2 ± 0.5 | 0.31 ± 0.01              | 0.33 ± 0.01                | 4                         | 15-C           | 4.8 ± 0.9  | 0.17 ± 0.01              | 0.18 ± 0.01                |
| 6-D            | 3.4 ± 0.6 | 0.34 ± 0.01              | 0.37 ± 0.01                |                           | 15-D           | 4.8 ± 1.1  | 0.04 ± 0.01              | 0.05 ± 0.01                |
| 6-E            | 3.6 ± 0.4 | 0.36 ± 0.01              | 0.40 ± 0.01                |                           | 15-E           | 1.4 ± 0.2  | 0.03 ± 0.01              | 0.04 ± 0.01                |
|   | 7-A   | 7-B   | 7-C   | 7-D   | 7-E   | 8-A   | 8-B   | 8-C   | 8-D   | 8-E   | 9-A   | 9-B   | 9-C   | 9-D   | 9-E   | 10-A  | 10-B  | 10-C  | 10-D  | 10-E  | 11-A  | 11-B  | 11-C  | 11-D  | 11-E  | 12-A  | 12-B  | 12-C  | 12-D  | 12-E  |
|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 7 | 13.0 ± 2.0 | 6.3 ± 1.1 | 8.1 ± 0.7 | 6.9 ± 1.3 | 11.7 ± 1.5 | 10.2 ± 1.2 | 7.5 ± 0.8 | 10.0 ± 1.1 | 7.0 ± 1.0 | 10.0 ± 0.9 | 11.4 ± 1.2 | 8.6 ± 0.9 | 11.5 ± 1.1 | 6.6 ± 0.5 | 11.3 ± 1.1 | 6.7 ± 1.1 | 3.12 ± 0.04 | 0.77 ± 0.02 | 1.22 ± 0.01 | 1.61 ± 0.02 | 2.20 ± 0.02 | 0.89 ± 0.02 | 0.82 ± 0.01 | 1.62 ± 0.01 | 1.37 ± 0.01 | 1.03 ± 0.02 | 1.04 ± 0.01 | 0.22 ± 0.01 | 1.09 ± 0.01 | 1.17 ± 0.01 | 3.42 ± 0.04 | 0.90 ± 0.02 | 1.38 ± 0.01 | 1.72 ± 0.02 | 2.39 ± 0.02 | 1.01 ± 0.02 | 0.90 ± 0.01 | 1.77 ± 0.01 | 1.49 ± 0.01 | 1.14 ± 0.02 | 1.12 ± 0.01 | 2.01 ± 0.01 | 0.24 ± 0.01 | 1.17 ± 0.01 | 6.5 ± 0.8 | 0.80 ± 0.01 | 0.70 ± 0.01 | 0.25 ± 0.01 | 0.83 ± 0.01 | 0.68 ± 0.01 | 1.17 ± 0.01 | 0.87 ± 0.01 | 0.91 ± 0.01 | 1.42 ± 0.01 | 1.75 ± 0.01 | 0.57 ± 0.01 | 0.89 ± 0.01 | 1.63 ± 0.01 | 0.75 ± 0.01 |
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