External Dose Estimation in an Early Stage after the Fukushima Daiichi Nuclear Power Plant Accident—Lessons Learned from Behavior Surveys Using Self-Administered Questionnaires—

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The Basic survey as a part of the Fukushima Health Management Survey was a self-administered questionnaire that asked subjects to record and send back information on their behavior in the 4 months after the Fukushima disaster. These behavior records were then digitalized, and individual estimates of external radiation exposure were made using daily ambient dose rate maps. Several issues arose in the process from receiving the completed questionnaires, estimating doses, and informing residents of the results. After sending out the questionnaires, a large number (8,000 responses per day at its peak) were returned over a short period, and these needed to be processed. To aid this, the number of staff involved in digitalizing the hand-written questionnaires was greatly expanded. Another issue was how to increase the response rate. While actions taken to raise the response rate did increase the number of responses to some extent, the response rate of the prefecture overall did not increase greatly. Such problems may be encountered in large-scale behavior surveys should another disaster occur in the future. This report gives an overview of these problems and how they were dealt with, which will provide a resource for public dose assessments should another disaster occur in the future.

KEY WORDS: Fukushima Health Management Survey, Basic Survey, individual external dose, behavior records, self-administered questionnaire, response rate.

1 INTRODUCTION

Immediately after the disaster at the Fukushima Daiichi Nuclear Plant, remarkable increases in ambient dose rates were observed, particularly in Fukushima Prefecture. However, at the time measurement devices, such as personal dosimeters and monitoring posts, were not widespread, which made it difficult to grasp the level of external radiation exposure among the public. Therefore, obtaining records of individual behavior (such as post-disaster evacuation behavior) from residents at an early stage, and using this information to understand external radiation exposure was considered. It was decided to conduct surveys of individual behavior as part of the “Fukushima Health Management Survey.” On May 27, 2011, a plan for a survey was examined at the first meeting of the Fukushima Prefectural Oversight Committee for the Fukushima Health Management Survey (below, Oversight Committee).1–3)

The Fukushima prefectural government commissioned Fukushima Medical University (below, FMU) to carry out the Fukushima Health Management Survey. The survey comprised a Basic Survey and 4 detailed surveys (thyroid ultrasound examination, comprehensive health check, mental health and lifestyle survey, pregnancy and birth survey).2, 3) Of these, the Basic Survey is intended to estimate residents’ radiation exposure doses. The purpose of the Fukushima Health Management Survey is to monitor the long-term health of Fukushima residents,4) and it is performed under the advisement of the Oversight Committee. The Oversight Committee meets about four times per year to receive progress reports from FMU.

At the first Oversight Committee meeting, a proposal for the mode of collecting records of residents’ behavior after the disaster was examined (Fukushima Health Management Survey, Basic Survey questionnaire). In addition, local mayors were sent a letter dated May 31 informing them that...
a Basic Survey was planned, and requesting they ask their residents to take the opportunity to record where they were and for how long in the days since March 11. At the second Oversight Committee meeting on June 18, 2011, a draft of the questionnaire that is currently being used was nearly completed. After these preparations, questionnaires were sent to initial-survey districts that were thought to have experienced relatively high radiation exposure (Namie town, Iitate village, Yamakiya district of Kawamata town). These districts received questionnaires earlier than other areas of the prefecture. First, questionnaires were delivered directly to people who had evacuated to Inawashiro town on June 30, then work on sending questionnaires by mail began. By July 15, a total of 27,256 questionnaires had been sent to people with known residences. Then, preparations began to expand the survey to all Fukushima residents. On August 26, questionnaires started being sent out to all Fukushima residents. By November 30, more than 2 million questionnaires had been sent, delivering them to almost all of the residents of the prefecture.

Several issues arose in the process from receiving the completed questionnaires, estimating doses, and informing residents of the results, and actions were taken to overcome these. This report gives an overview of these issues to provide a resource for public dose assessments should another disaster occur in the future.

II BASIC SURVEY OUTLINE

2.1 Basic survey questionnaire and subjects

The Basic survey was a self-administered questionnaire that asked subjects to record and send back information on their behavior in the 4 months after the disaster. These behavior records were then digitalized, and individual estimates of external radiation exposure were made using daily ambient dose rate maps and a calculation program. Figure 1 shows a conceptual diagram of how doses were calculated. The Basic survey was approved by the ethical review committee of Fukushima Medical University (No. 1257, 1275, 1294).

For the 4-month behavior records, the subjects were asked to record their behavior in detail during the period when ambient dose rates were particularly high (until March 25) (Fig. 2). After this period, the recording style was simplified to entering the places they stayed, and the average time spent outside, on errands, and in other such locations.

The subjects of the Basic Survey were people who were registered residents of Fukushima Prefecture from March 11 to July 1, 2011. Lists of registered residents during this period were obtained from municipal governments to create a list of subjects for the basic survey. In addition, the following people were sent questionnaires if requested: (1) people who lived in Fukushima Prefecture from March 11 to July 1 but were registered as residents of other prefectures, (2) residents of other prefectures who worked or attended school in Fukushima Prefecture from March 11 to July 1, and (3) residents of other prefectures who stayed temporarily in Fukushima Prefecture from March 11 to 25. People who fell into categories 1 to 3 were treated as “temporary residents,” and their data was totaled separately from people who were registered Fukushima residents at the time of the disaster.

2.2 Outline of the characteristics of the Basic Survey and its results

After the disaster, a number of domestic and international organizations issued reports on external radiation exposure, but these all were based on assumed behavior patterns. For example, in a report by UNSCEAR, doses were evaluated based on 18 evacuation patterns that were thought to be representative, typical ratios of time spent indoors and outdoors, and other assumed variables. A report by the World Health Organization estimated external doses based on an assumed lifestyle pattern of being indoors for 16 hours and outdoors for 8 hours. Some other studies estimated external doses for extreme cases that were assumed to be outdoors for...

![Fig. 1](image-url) Conceptual diagram of dose estimates for the Basic Survey (This example is simplified, so it does not include the doses received during movement from place to place on March 12, but in the actual calculations, doses during movement were included).
24 hours. Therefore, the Basic Survey is characterized by dose assessments that are based on individual behavior records obtained from self-administered questionnaires.

Another characteristic of the Basic Survey is that the subjects are notified of their individual dose estimates. This is in line with the overall purpose of the Fukushima Health Management Survey: (1) to estimate external dose of the people in Fukushima Prefecture, which is essential for prevention, early detection and treatment of diseases, and (2) to monitor and promote the long-term health of Fukushima residents. In other words, one aspect of the Basic Survey is to publicize individual dose distributions and other data by municipality or by district. Another aspect is to provide a health service to residents by providing them with individual dose estimates they can use to manage their health in the future (Fig. 3).

As shown in Fig. 3, after the questionnaires are sent back, the behavior records are checked to determine whether sufficient information to make dose estimates was provided. Sufficient information means the behavior records are continuous with no breaks, and the locations where people stayed could be identified (changes in longitude and latitude could be tracked). If it is determined there is sufficient information for a dose estimate, work begins on digitizing the questionnaire (data entry). Because the behavior records are entered into the questionnaires by hand, they need to be turned into electronic files so they can be processed by the dose calculation program. After an electronic file is created, the behavior record is sent to the National Institute of Radiological Sciences (NIRS) with all personal information (questionnaire number, name, age) removed. The NIRS then estimates the dose using a program it developed and sends the results back to FMU. Age is a form of personal information, so this is stored by FMU. The estimates provided by NIRS are then used to estimate the individual’s dose using age as a weighting factor. This then serves as the final dose.

The estimated dose is then sent to the individual accompanied by a brief document explaining radiation exposure doses. While the questionnaire asks subjects to enter their behavior records for 4 months after the disaster (up to July 11, 2011), some subjects do not provide records for 4 months. In such cases, dose estimates are made for the period for which continuous records were provided, and the individual is notified of the estimate for this period. The Oversight Committee receives frequent updates on the latest status of dose estimates, notifications, and other matters. As of March 31, 2017, dose estimates had been made for 552,034 people, including those with behavior records of less than 4 months, and results had been sent to 551,753 people.

For the other aspect of the survey, the individual doses were totaled by municipality, district, and other factors, and announced at Oversight Committee meetings. Looking at the entire prefecture (initial survey + full-scale survey), the effective dose from external radiation exposure in the 4 months after the disaster among the respondents (excluding radiation workers) was less than 1 mSv for 62.2%, less than 2 mSv for 93.8%, and less than 5 mSv for 99.8% (Table 1). Because people continue to respond to the questionnaire,
the latest data on dose distribution is regularly reported to the Oversight Committee. Moreover, materials from Oversight Committee meetings are translated into English and posted on the FMU homepage so people overseas can view them. The survey results have also been published in international journals and presented at international conferences.10, 15–17)

III ISSUES THAT AROSE DURING THE BEHAVIORAL RECORD SURVEY

First, the questionnaire used to record post-disaster behavior was directly delivered to people who had evacuated to Inawashiro town on June 30. Then, work on sending questionnaires to the initial-survey districts by mail began. Starting in late August, questionnaires were sent to all Fukushima residents by mail. Since then, a variety of issues have been faced, including processing large numbers of questionnaires, dealing with questionnaires with incomplete records, and attempting to raise the response rate. The following describes these issues and how they were dealt with.

3.1 Processing large numbers of questionnaires

After sending out the questionnaires, a large number were returned over a short period, and these needed to be processed. At the fourth Oversight Committee meeting (October 17, 2011),7) it was reported that responses had been obtained from about half of the subjects in the initial-survey districts (47.5%, 13,884 out of about 29,000), and about 80,000 responses to the full-scale survey had come in, for a total of 93,428 responses (Table 2).18–24) At this point there were 40 people doing data entry (turning the questionnaires into electronic files). Thereafter, while the number of responses from the initial-survey districts grew slowly, responses to the full-scale survey increased to a pace of about 8,000 per day.8) As of November 30, 2011, there were 356,715 responses to the full-scale survey, a drastic increase of about 280,000 responses from October 11. It was at this time that the first dose distributions were published. Among the 1,589 respondents in the initial-survey districts (radiation workers excluded), about 62% had doses less than 1 mSv.

At a press conference on February 20, 2012,19) it was reported that dose estimates had been performed for 9,744 people (radiation workers in the initial-survey districts excluded). Of them, 57.8% were less than 1 mSv and 99.3% were less than 10 mSv. This showed that even in districts thought to have relatively high doses, almost all doses were less than 10 mSv. As of March 2012, 451,446 responses had been obtained and the data entry staff had increased from 40 to 700 people, who were engaged in the work needed to make dose estimates.20) The number of dose estimates completed increased rapidly,
going from 25,667 on May 31, 2012, to 122,798 on August 31, to 233,901 on October 31 (Table 2). At its peak, an enormous 8,000 responses per day were arriving.

The people of Fukushima needed to be informed of the dose estimates as soon as possible. To aid this, the number of staff involved in digitalizing the hand-written questionnaires was greatly expanded starting in 2012, which helped address the situation. These actions were effective, and by October 31, 2012, dose estimates had been completed for about half (49.4%) of the responses. The number of completed dose estimates was 394,369 on January 31, 2013, at which point estimates had been completed for more than 80% of the responses. Progress had gradually been made on informing the public of the results of the estimates, and at that point 361,752 people had been informed of the results, which was 75.8% of the number of responses.

If the target population was much smaller (e.g. only residents in the initial-survey districts with high ambient dose rate), responses could have been dealt with a shorter period. However, even residents in districts with relatively low ambient dose rate might have had anxiety for their exposed doses. In this respect, the Basic Survey that targets all Fukushima residents has contributed to provide information on individual doses for residents in wide areas including non-evacuated areas. On the other hand, disadvantages resulting from the large number of target population were that (1) dealing with responses took time and (2) enough explanation on estimated doses to individuals was lacking.

### Table 2 Growth in the number of responses and progress in completing dose estimates.

<table>
<thead>
<tr>
<th>Date of finalizing report</th>
<th>Number of responses (initial + full-scale surveys)</th>
<th>Number of completed dose estimates</th>
<th>Date of publicizing report</th>
<th>Place of publicizing</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/10/11</td>
<td>95,428</td>
<td></td>
<td>2011/10/17</td>
<td>4th Prefectural Oversight Committee Meeting</td>
<td>7</td>
</tr>
<tr>
<td>2011/11/30</td>
<td>371,039</td>
<td>1,727</td>
<td>2011/12/13</td>
<td>1st press conference on progress report</td>
<td>8</td>
</tr>
<tr>
<td>2012/1/20</td>
<td>426,932</td>
<td>1,727</td>
<td>2012/1/25</td>
<td>5th Prefectural Oversight Committee Meeting</td>
<td>18</td>
</tr>
<tr>
<td>2012/1/31</td>
<td>431,720</td>
<td>10,468</td>
<td>2012/2/20</td>
<td>2nd press conference on progress report</td>
<td>19</td>
</tr>
<tr>
<td>2012/3/31</td>
<td>451,446</td>
<td>10,468</td>
<td>2012/4/26</td>
<td>6th Prefectural Oversight Committee Meeting</td>
<td>20</td>
</tr>
<tr>
<td>2012/5/31</td>
<td>465,041</td>
<td>25,667</td>
<td>2012/6/12</td>
<td>7th Prefectural Oversight Committee Meeting</td>
<td>21</td>
</tr>
<tr>
<td>2012/8/31</td>
<td>470,593</td>
<td>122,798</td>
<td>2012/9/11</td>
<td>8th Prefectural Oversight Committee Meeting</td>
<td>22</td>
</tr>
<tr>
<td>2012/10/31</td>
<td>473,841</td>
<td>233,901</td>
<td>2012/11/18</td>
<td>9th Prefectural Oversight Committee Meeting</td>
<td>23</td>
</tr>
<tr>
<td>2013/1/31</td>
<td>477,121</td>
<td>394,369</td>
<td>2013/2/13</td>
<td>10th Prefectural Oversight Committee Meeting</td>
<td>24</td>
</tr>
</tbody>
</table>

3.2 Dealing with incomplete behavior records

Another issue that arose was how to deal with incomplete behavior records. Changes in a subject’s latitude and longitude needed to be tracked based on information provided in the behavior records, such as addresses and building names. For instance, a record that reads, “I was at a relative’s house” on a certain date does not provide an address or building name, so changes in latitude and longitude cannot be tracked, which means the dose cannot be estimated. To deal with incomplete records, individual respondents needed to be contacted by telephone to supplement their behavior records (see Fig. 3).

At the sixth Oversight Committee meeting, it was reported that the number of staff working on supplementing records had been increased from 6 to 12. Records were said from about 15% of the initial responses reportedly needed to be supplemented. After contacting these individuals and supplementing the questionnaires, work could proceed on the dose estimates. The number of responses that needed supplementation was 69,000 on October 31, 2012, and peaked at 76,000 on January 31, 2013. Sufficient staff for supplementing the records was secured, and they worked persistently. A variety of attempts were made to contact each respondent. For example, letters were sent when an address but no phone number was provided on the questionnaire. At an Oversight Meeting on June 5, 2013, it was reported that the number of responses needing supplementing had declined to 46,000. As of March 31, 2017, there were about 13,600 subjects left with records that were classified as difficult to supplement. This 13,600 figure includes questionnaires that need supplementing but were without clear contact information, as well as responses that were sent in with almost nothing filled in. In both cases, an estimate could not be made even though a response was provided, so they are treated as “difficult to supplement” (unable to make a dose estimate) responses.

3.3 Increasing the response rate

The response rate to the questionnaire (full-scale survey + initial survey) was in the 20% range at the end of 2011, and did not increase much thereafter. A variety of actions were taken to try to raise the response rate. At the fifth Oversight Committee meeting on January 25, 2012, it was reported that a variety of actions had been taken, including (1) posting advertisements in prefectural bulletins, newspapers, and elsewhere; (2) creating a DVD describing how to fill out the questionnaire and uploading it to a homepage; (3) asking people to respond to the Basic Survey in notices about thyroid ultrasound examinations and other health checks; and (4) holding explanatory sessions about filling out the questionnaire.

At the eighth Oversight Committee meeting on September 11, 2012, a summary of the actions taken to raise the response rate (content of actions, number of times, number of subjects, etc.) was reported (Table 3). Such summaries were presented at each subsequent Oversight Committee
meeting until the 23rd meeting. As Table 3 shows, a variety of approaches were used, which included going directly to residents, through companies, and through the media.

During this time, the main action taken was visiting companies and requesting that they ask their employees to submit questionnaires. At the eighth Oversight Committee meeting, it was reported that 168 places had been visited (Table 3) and at the ninth meeting, it was reported that 495 places had been visited.23) Companies in Fukushima Prefecture were visited and asked to help submit the questionnaire, such as in companywide emails and at morning meetings. Another support counter at venues for thyroid ultrasound examinations where people could be provided for filling out the questionnaire. Figure 4 shows how one of these support counters looked.

Thyroid ultrasound examinations are performed for Fukushima residents age 18 and younger out of concerns about thyroid radiation exposure from the nuclear disaster.24) Thyroid ultrasound examinations are often performed at schools or hospitals, and sometimes at public facilities for children not yet old enough for school. The public facilities that host the examinations usually have plenty of space, so when possible a counter to provide support for filling out questionnaires is set up. After finishing the examination, children and their guardians are called over and asked if they would like to fill out a questionnaire. Those who say yes are given an explanation and provided with help filling out the form.

Further, the questionnaire that was initially made needs to be modified to fill out the behavior records on an hourly basis (Fig. 2). Therefore, a new questionnaire that was easier to fill out (simplified version) was created as part of efforts to raise the response rate. A simpler input mode would make the questionnaire easier for people to fill out, but it might also reduce the accuracy of the dose estimates. A simplified questionnaire was created after considering how to balance the estimate accuracy with the ease of filling out the form.25, 26) Before using the simplified questionnaire, small groups were asked to fill out the simplified version and the original questionnaire (hereafter, the questionnaire that was used initially will be referred to as the “original questionnaire”) to check the accuracy of the dose estimates. Of the 143 people who participated, comparisons of the simplified version and original questionnaire were possible for 91 people. The results showed that among people who frequently moved residences or workplaces, the difference in estimates between the simplified version and original questionnaire were somewhat large. Nonetheless, overall a high correlation coefficient was observed. The range of differences in dose estimates between the simplified version and original questionnaire was −0.4 mSv to +0.6 mSv. A survey responded by 89 of the 143 participants showed that it took a mean 16.5 minutes to fill out the simplified version, which was about one-third of the time it took to complete the original questionnaire.25)

Based on this result, the simplified questionnaire was put into use among a limited number of subjects. That is, because the difference in estimates between the simplified version and original questionnaire were somewhat large for people who

Table 3 Summary of activities to encourage responses (reported on September 11, 2012).

<table>
<thead>
<tr>
<th>Approaches</th>
<th>Activities</th>
<th>Places and duration of activities</th>
<th>Number of activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly to residents</td>
<td>Visit to temporary houses by student volunteers</td>
<td>Fukushima City</td>
<td>12 times</td>
</tr>
<tr>
<td></td>
<td>Support for filling out questionnaire on-site at</td>
<td>Fukushima City, Koriyama City</td>
<td>30 times</td>
</tr>
<tr>
<td></td>
<td>information centers</td>
<td>Jul. 2 to Aug. 31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support for filling out questionnaire on-site at</td>
<td>Fukushima City</td>
<td>6 times</td>
</tr>
<tr>
<td></td>
<td>ultrasound thyroid examination</td>
<td>June 6 to Jul. 11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support for filling out questionnaire on-site at</td>
<td>Fukushima Medical University Hospital</td>
<td>3 times</td>
</tr>
<tr>
<td></td>
<td>a hospital health examination</td>
<td>May 28 to 30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support for filling out questionnaire on-site at</td>
<td>Iitate Village</td>
<td>6 times</td>
</tr>
<tr>
<td></td>
<td>venue of ultrasound examination</td>
<td>May 28 to June 3</td>
<td></td>
</tr>
<tr>
<td>Approach through companies</td>
<td>Visit to companies to ask employees for submission of questionnaire</td>
<td>Whole area of Fukushima Pref.</td>
<td>168 times</td>
</tr>
<tr>
<td></td>
<td>Since Feb 1 (in progress)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach through mass media</td>
<td>Announcement of Basic Survey through radio</td>
<td>Whole area of Fukushima Pref.</td>
<td>Once per day</td>
</tr>
<tr>
<td></td>
<td>Since March 10, 2012 (in progress)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Announcement of Basic Survey through newspaper and TV</td>
<td>Whole area of Fukushima Pref.</td>
<td>Newspaper: 12 times</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TV: 7 times</td>
</tr>
</tbody>
</table>

Fig. 4 Each of two FMU staffs (wearing a green jacket) give an explanation to 3 Fukushima residents at a counter that provided support for filling out questionnaires.
moved around a great deal, the simplified questionnaire was limited to people who moved their residence or workplace once or less during the first 4 months after the disaster. The simplified questionnaire was sent to people who had not yet submitted the original questionnaire and who were eligible for thyroid ultrasound examinations, as they would probably be able to understand a significance of radiation exposure dose estimation (about 250,000 people). These were sent from the end of November through December 2013. The simplified questionnaire was not only used with subjects of the thyroid ultrasound examinations, but was later used widely in activities aimed at helping people fill out the questionnaire. As of March 31, 2017, there had been 73,189 responses to the simplified questionnaire.14) This had some effect, particularly in the Aizu and Minamiaizu districts, where the response rate increased to 27.2% as of June 30, 2015. Related to this, the examination of representativeness described below was planned after this.

**Figure 5** (above) shows changes in the response rate over time up to June 30, 2015, and **Fig. 5** (below) shows changes in the response rate after the main actions to raise the response rate were introduced.27) In most cases, multiple actions to raise the response rate were being performed at once, so there is not necessarily a one-to-one correlation between an action and a change in the response rate. For example, **Fig. 5** (below) shows that the effect of (4) (filling out and sending back the simplified questionnaire) continued into the periods when (5) and (6) were introduced.

Because the survey covered all Fukushima residents (about 2.06 million) and included districts where ambient dose rates were relatively low (Aizu, Minamiaizu, etc.), raising the response rate for the entire prefecture was difficult. While actions taken to raise the response rate did increase the number of responses to some extent, the response rate of the prefecture overall did not increase greatly. The rate was 27.2% as of June 30, 2015. Related to this, the examination of representativeness described below was planned after this.

### 3.4 Test of representativeness

While actions to raise the response rate continued, a major improvement in the response rate over the entire prefecture did not occur. This raised the question whether the people who responded to the questionnaire had higher (or lower) doses, even compared to people in the same district. Therefore, it was investigated whether the responses that had been obtained, and the estimates of external radiation exposure based on them, were representative of the residents of Fukushima Prefecture (survey of representativeness). In the survey, the doses of people who responded to the Basic Survey were compared to the doses of people who had not yet responded to the Basic Survey. If equivalence could be shown, then the respondents up to that point could be considered representative of their districts. The results of the survey of representativeness were published in a separate report.29) A simple outline of this is as follows.

In the equivalence test, if the 95% confidence interval of the difference in mean values from 2 groups is within a certain range (equivalence margin), the groups are seen as equivalent. To examine the representativeness of the respondents using this method, Fukushima Prefecture was divided into 7 districts, and subjects of the Basic Survey were selected randomly from each district. Among them, people who had already responded were excluded, and those who had not yet responded were interviewed at home. It was sometimes difficult to obtain responses at the first visits because people were often not at home. Multiple visits were sometimes necessary to obtain enough responses. As a result, responses were obtained from about 37% of the 2,645 randomly selected subjects. Dose estimates were then made for these responses, and the doses were compared to the doses of people who had already responded before the interview survey.

In all 7 districts, the 95% confidence interval of the difference in mean doses between the two groups was within the equivalence margin (here set to 0.25 mSv), which shows that the groups’ doses were equivalent. Moreover, the dose distributions of the people who responded to the questionnaire before the interview survey, the randomly selected people who had already responded, and the people who responded to the interview survey were largely similar in all the districts. Based on this, it was concluded that the dose distributions obtained so far were representative of the residents of Fukushima Prefecture.28)

### IV DISCUSSIONS

#### 4.1 Future prospects for the Basic Survey

The survey of representativeness described above indicates that although the response rate was only about 27% for the entire prefecture, the dose distributions obtained so far are representative of all Fukushima residents. This demonstrates that the part of the survey involving surveying dose distributions of external radiation exposure in the early stages after the disaster was effective in reaching some conclusions. However, as described in section 2, another aspect of the Basic Survey was to provide a service to the residents of Fukushima Prefecture by informing people who wanted information on their radiation doses in the early stages after the disaster of the results of the dose estimates. Going forward, if questionnaires are received from Fukushima residents who want information on early post-disaster radiation doses, the plan is to continue this service by estimating their doses and informing them of the results.

Even in fiscal 2017, six years after the disaster, Fukushima residents who received assistance filling out the questionnaire at venues for thyroid ultrasound examinations have expressed gratitude for the support. In light of this, the office will be maintained where dose estimates and notifications for the Basic Survey can continue.

In addition, research has been conducted on applying the behavior records obtained from the Basic Survey to other purposes than estimation of external dose. An analysis based on the behavior records for residents in Iitate village showed that the amount of time spent outdoors per day was about 2 hours. Based on this it was reported that the assumption of 8 hours spent outdoors, which is commonly used in calculating external radiation exposure, overestimates the external exposure dose.30)
The behavior records and individual external doses obtained by the Basic Survey are stored in a database, together with results for other surveys of the Fukushima Health Management Survey such as whole-body counter (WBC) measurements and thyroid ultrasound examinations. The database makes it possible to analyze a relationship between the data obtained by the Basic Survey and the results for other surveys on a personal basis. Such analysis basically uses data on residents registered in Fukushima Prefecture (excluding temporary residents) at the time of accident.

For example, attempts have been made to evaluate thyroid doses using the behavior records and simulations of the...
atmospheric dispersion of radioactive substances released,\(^\text{31}\) and to analyze the relationship between evacuation behavior and internal radiation exposure estimated by WBC measurements.\(^\text{32}\) Such efforts are aimed at applying behavior records to reconstructing internal doses in early stages. As another example of analysis which utilizes the database, results for thyroid ultrasound examinations are analyzed in relation to the individual doses. The Basic Survey results (four-month individual external doses) were available for 63 confirmed or suspected thyroid cancer patients.\(^\text{34}\) The maximum individual dose among them was found to be 2.2 mSv. Also, the distribution of individual doses among them was similar to that of overall residents. Since thyroid ultrasound examinations are still going on now, such analysis will also be continued.

As mentioned before, the Basic survey was approved by the ethical review committee of Fukushima Medical University. However, applying the behavior records to other purposes than estimation of external dose might be beyond the scope of the Basic Survey approved by the ethical review committee. In such cases, research will be started after getting a new approval.

4.2 Estimation of initial-stage external dose after nuclear disasters

Estimation of external radiation exposure based on the behavior surveys and ambient dose rates were also conducted after the Tokaimura nuclear accident (JCO accident).\(^\text{35}\) At that time, an NIRS group surveyed the behavior of local residents by interviewing them individually. They estimated exposure doses for each individual by combining the behavior records with dose rates based on the distance from the site of the accident, then informed the residents of the results of the estimates by visiting them individually.\(^\text{36}\)

Considering the external dose estimation in the two cases (Fukushima disaster and Tokaimura accident), the method of using behavior record surveys and ambient dose rates to estimate individual external radiation exposure can be considered an effective means of evaluating initial-stage external radiation exposure in situations that involve radiation exposure of the general public, and when it is not possible to quickly distribute personal dosimeters. On the other hand, one limitation of behavior record surveys is that they rely on people’s memories. On this point, using mobile phone GPS functions may be an effective means of understanding behavior.\(^\text{37}\) However, this would not provide information on whether a person is inside or outside, or on the type of building (level of shielding from the building), and data may not be available during large-scale power outages. In addition, not every person necessarily has a mobile phone with GPS functions. Therefore, questionnaire-style behavior surveys are thought to be an effective means of assessing individual external radiation exposure in the early stages after a disaster. This method is also recommended in a European report on emergency preparedness.\(^\text{38}\)

That being said, problems such as those described in chapter 3 may be encountered in large-scale behavior surveys. Experience in dealing with these problems tells us that (1) behavior questionnaires must be easy to fill out but still ensure a certain degree of accuracy in the estimates, (2) the survey should start before memories fade, and (3) enough staff should be secured to handle the survey. On the other hand, care/support for residents should be a high priority in early days of disasters. Although it’s important for future analysis to obtain data for the surveys, it is necessary to balance care/support for residents and survey needs.

V SUMMARY

The Basic Survey was launched to provide a health service to residents by informing people who wanted information on their radiation doses in the early stages after the Fukushima Dai-ichi Nuclear Power Plant accident. It consists of a self-administered questionnaire that asked subjects to record and send back information on their behavior in the 4 months after the accident. The individual external doses have been estimated by using digitized behavior data and a computer program which included daily gamma ray dose rate maps after the accident. However, several issues arose in the process from receiving the completed questionnaires, estimating doses, and informing residents of the results, and actions were taken to overcome these. This report gives an overview of these issues and how they were dealt with, which will provide a resource for public dose assessments should another disaster occur in the future.

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