Chapter 20
A Study of a Development of Internal Exposure Management Tool Suited for Japanese Diet Behavior

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Abstract After the Fukushima Nuclear Power Plant accident, one of the main issues at stake was the potential intake of contaminated foodstuff by residents of the affected areas. In this context, the importance of the management of the internal exposure by food intake has emerged. For this purpose, a system was developed for estimating the amount of the radioactivity ingested through the diet in order to manage the internal exposure evolution of exposed people. The ultimate goal of this system is to consider all the radiation exposure data including medical exposure in an integrated manner.

In this perspective, a tool that was used for internal exposure assessment in Europe after the Chernobyl disaster has been adapted to be suitable to Japanese diet behavior. The tool was implemented in a Web application in order to estimate the amount of radioactivity in the dish and to manage the internal exposure history of the individuals. This system automatically collects the test results of radionuclide in foods available on the web.

It manages the individual internal exposure history estimating the amount of radioactivity in the ingested dish. The developed application enables individual to manage his/her protection by checking radioactivity ingestion history and

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determining to eat or not the dish according to the amount of radioactivity in the dish. This system, which has the potential to contribute to the radiation protection culture of people living in the contaminated areas of Fukushima Prefecture, has been evaluated by specialists of radiation protection. The following step will be the test of the system by the individuals themselves.

Keywords Internal exposure management • Internal exposure from food intake • Radioactivity ingestion history management • Radiation protection culture

20.1 Introduction

A large amount of radioactive materials was released into the environment by the Fukushima Daiichi nuclear power plant accident caused by the Great East Japan Earthquake, leading to an increasing concern of the citizens about radiation. As a result, not only the concern about the external radiation exposure from the environment but also the growing concern about internal radiation exposure related to food deepened awareness of the importance of a global exposure dose management. It is the purpose of this research to handle and to unify the information about the radiation exposure for affected individuals.

According to ICRP Publication 111 [1], optimization of radiation protection for the residents living in the contaminated areas is the driving principle. This cannot be achieved without engaging the affected people in the process and in this perspective information and dialogue meetings on radiation protection, and a variety of lectures have been carried out [2]. Upon preliminary investigation of the present study, the authors participated in dialogue meetings, which took place in the affected areas. This was an opportunity to hear the voice of the residents. What we learned was that many people in the absence of measurements related to their own situation were anxious about the situation and as a result had no other choice than imposing themselves restrictions in their diet. This was perceived as a strong constraint on the day-to-day life and induced changes in the cultural habits on food consumption. Although the first measurements made in the Prefecture were indicating concentration values in foodstuff much lower than those initially expected or announced by different voices, the consumers were generally still reluctant to buy products from Fukushima Prefecture. This confusing situation led us to promote a database providing the available information in order to better inform the residents.

For food on the market, radioactivity measurement results have been published by the Ministry of Health, Labour and Welfare (MHLW) [3], local governments [4, 5], and Japan Agricultural Cooperatives (JA) [6]. As for the foods that residents gathered on kitchen gardens, forests, rivers, and in the sea, the community centers have provided equipment to measure the radiation, etc., so it has become possible to know the amount of radioactivity in food in almost all cases. However, the amount of radioactivity is expressed in Bq/kg, and it is difficult for the local residents to directly estimate the influence of these values on the total dose they receive (expressed in mSv). In order to determine themselves whether or not to eat the various food products, it is useful to know how much radioactivity they take when they eat those products, the degree of internal exposure, and also the quantity of radioactivity discharged from the body. In this perspective a tool which provides information about all these aspects was considered as very helpful. After the Chernobyl accident, the ETHOS project and the CORE program [7, 8] in the contaminated areas of Belarus provided education for local residents about radiation protection to favor their involvement in their own protection. A software for internal exposure assessment called CORPORE has been developed and used in this program in cooperation with Norwegian radiation protection experts. With this software, it is possible to describe and analyze the results of whole body counters (WBC) measurements. Using this tool allows registering the amount of radioactivity taken during the daily diet and also allows health care workers to open a dialogue with individuals about the radiological quality of the food. By doing so the tool allows to enhance the awareness of residents about the risk of internal exposure and also to help individuals to make informed choices about their diet. Although using this tool to find the cause in the WBC measurement results is a so-called reverse direction, it allows to know how much radioactivity is consumed. The estimate intake of exposure amount taken when people ingest the food is displayed in a graph, which also shows the personal history of the accumulation and discharge of radiation. By using this graph people can decide what is not suitable to eat/suitable to eat sometimes/the amount suitable to eat/occasionally suitable to eat. Finally this approach allows residents to easily be able to determine what to eat.

In this study by using the mechanisms and models of CORPORE taking into consideration the situation in Japan and Japanese eating habits, we implemented and verified our method of internal exposure management and acquiring information about food.

20.2 Methods

The original CORPORE was implemented to respond to the Belarus and Norwegian situation by handling the food products separately and considering two modes of ingestion: chronic intake and episodic intake. Therefore, its use required to be adapted to the typical Japanese environment. Japanese seldom keep eating the same menu everyday. They often eat various dishes using various food products. It is more natural and easy to manage the ingredients rather than dishes for them. Thus, we decided to handle ingestion as dishes for the new system.

Original CORPORE handles only cesium-137 (Cs-137). Other radionuclides were also required to consider in Japan. It was issued for iodine-131 (I-131), cesium-134 (Cs-134), and Cs-137 radioactivity measurements. Although without any details about each food product, the results were also presented for strontium-90(Sr-90) and plutonium measurement on market basket methods [3]. For this reason, it was decided that the support of multi-nuclide is also required. Original CORPORE was

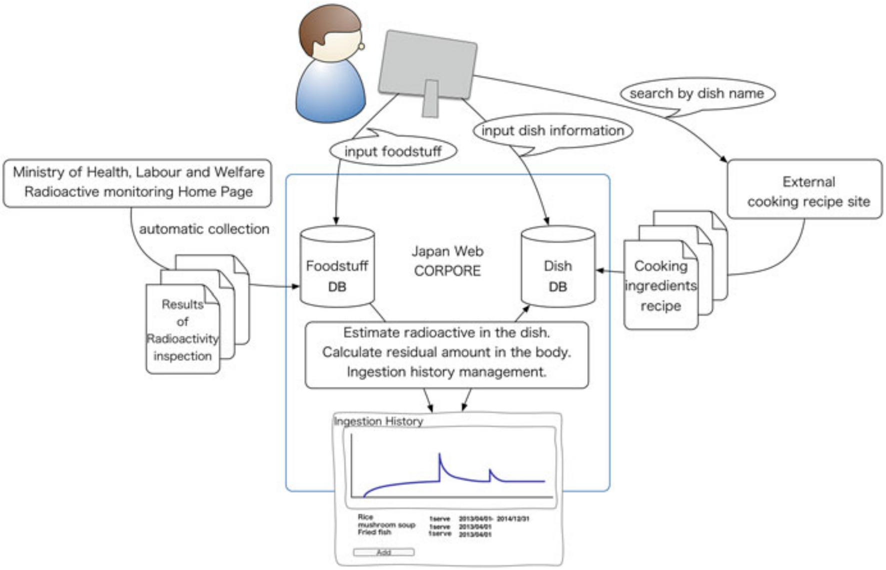

Fig. 20.1 A diagram of Japan Web CORPORE

basically intended for use by radiation protection and medical personnel. In order to be used by residents, the user management system and intake history management system have been developed. Original CORPORE also has statistical functions about the intake status for assessment in order to display the position of the resident in the group. All these features have been kept.

In order to adapt the original CORPORE to the Japanese situation, it is developed as a Web application for widespread use. A database structure allows managing ingestion of food products as dish. It hence supports to various nuclide types. Applying user management function, users can manage their own intake history respectively. To facilitate complicated food information input, food and dish input system is applied so that forward-direction usage can be realized. All these functions are presented in Fig. 20.1 and details are explained below.

20.2.1 System

Local residents can enter their own dish to evaluate their contamination level, so they can make the exposure management of themselves by browsing the radioactivity intake information and internal exposure information. They are also able to access it and use it from personal computers or smart phones through the Internet, as it is developed as a Web application. To operate in typical server configurations, MySQL 5.5 database system, most popular open source database system in the world [9], was used, and it was implemented in PHP 5.5, Hypertext Preprocessor which is a server-side scripting language [10], to work on typical web server applications such as Apache 2.4 [11], etc. Also, it is available from the general viewing environment, and is successfully displayed in Internet Explorer 9 or higher, Google Chrome version 10.0.648 or higher and Safari version 5.0 or higher.

20.2.2 Database Structure

In order to input food intake situations to match the Japanese food environment, we considered the modification of the food database structure of the original CORPORE. It was initially limited to the food database, and we enlarged it to the ingredients database.

Also, the original CORPORE allowed only Cs-137 input, while in the modified version the database structure corresponds to the multi-radionuclide species. Presented in the survey results by the MHLW released I-131, Cs-134, Sr-90 and plutonium (Pu-238, Pu-239, Pu-240) became a possible input.

20.2.3 Food and Cooking Information Input

Radioactivity test results announced from time to time by the MHLW turn into DB automatically, and this information is available to use for products. As for the food which is ingested daily, by applying the technology developed by Kawashima et al. [12], in cooperation with external recipe information sites, it is possible to avoid the trouble of inputting all the information about materials. Cooking information can be reused as a template.

20.2.4 User Management

To perform user management, the user is enabled to browse his/her intakes in the history of radiation continually and record meals.

In addition, it allows managing the users' rights, such as general user, user with administrative privileges; medical user to make the assessment and research user to make the research were prepared.

The medical user privileges include a privilege to view all the information of the population to perform the individual exposure assessment. The research user privileges include a privilege to view anonymized information about the intake of the population.

20.2.5 Form of Use

Original CORPORE was used in Belarus as an assessment tool (1) to determine the amount of radioactivity in the body using the WBC measurements as inputs, (2) to engage a dialogue with the residents on their diet in case the internal contamination levels were significantly higher than the average level, (3) to analyze the estimated exposure dose using the graph to display it; thus, it is the reverse direction to explore the cause from the result. Displaying the radiation dose that is expected by ingesting the food is not only the opposite direction to determine whether to eat or not. Also, the ingested radioactivity substance amount is recorded, because it is assumed that a possible use of its dose can happen in the future again. This data is saved in history of the daily diet, and it can be displayed in a graph to see the remaining radioactivity quantity in the body.

Moreover, it can be used as an assessment tool, since it matches the functions of the original CORPORE, and in the present system the input and statistics of WBC measurement results are displayed, too.

20.3 Results

In the Web version of CORPORE Japan, it is possible to access the Web application through the Internet, perform user management on the basis of the food ingredients input to make a meal, learn about ingested food information for each user, and display a graph of radioactivity intake and biological half-life discharge status, as well as to be able to confirm oneself the graph of intake and discharge status of radioactivity on the browser. From 0-year-old to 1-year-old, from 2-years-old to 5-years-old, from 6-years-old to 10-years-old, from 11-years-old to 15-years-old the ingested radioactivity is reduced by each of the biological half-life factor by 16-years-old of age or older, and the user's age appearance is displayed as a graph (Fig. 20.2).

As an assessment function, similar to the original CORPORE, it is possible to confirm the statistics display about any users' position among the intake average and make groups of the population on the browser (Fig. 20.3).

Furthermore, the product database is updated periodically through the access to the MHLW website which is obtained automatically, to see the results of the radioactivity tests. In April 2015, about 1.2 million cases of food radioactivity test results were published and are available as contamination information. Although it was confirmed that the database allows entering not only Cs-137 information but also other radionuclides, however, currently this system implemented only Cs-137 biological model, hence the result graphs of such other nuclides are not shown.

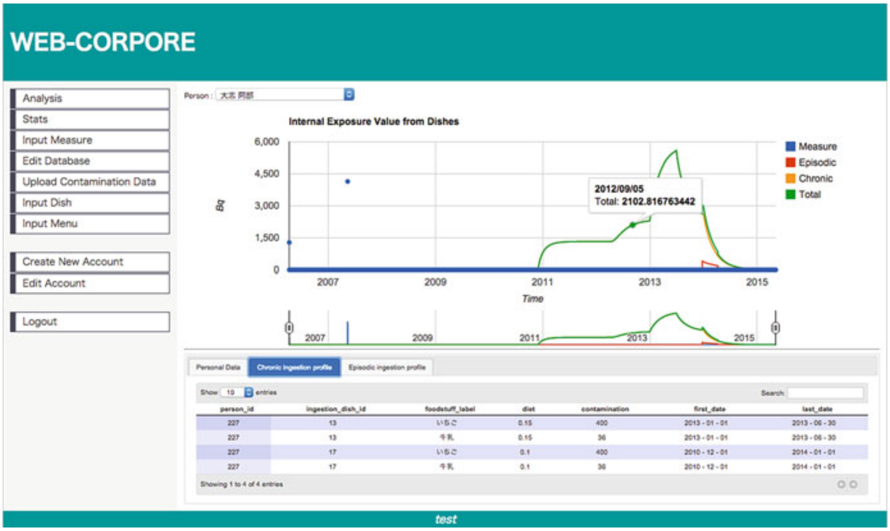

Fig. 20.2 An analysis screen shows the history of radioactivity ingestion and reduction

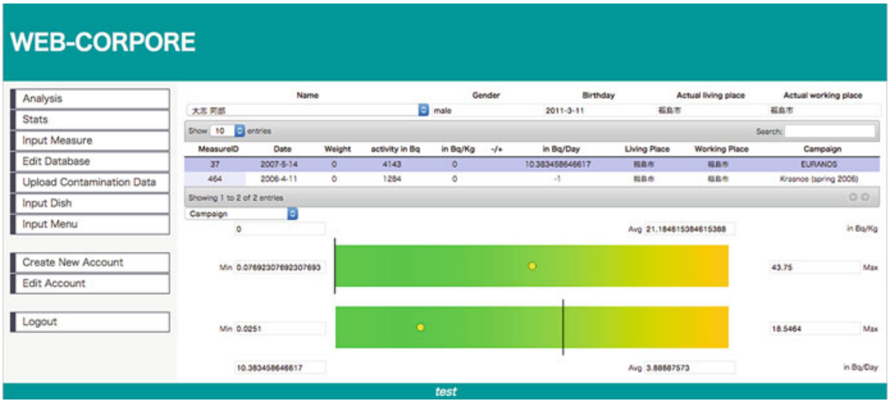

Fig. 20.3 A stats screen shows user's position among the intake average and make groups of the population

20.4 Discussion

20.4.1 Verification of the Usability

As a method of using this system, before cooking any meal or buying any ingredients, one can enter the system from a personal computer or a smart phone, enter the meal ingredients one has access to. By doing this, one will estimate the intake. This way allows obtaining the history of radioactivity intake and estimates the information about the intake of internal exposure dose, so one can make the decision to reduce the amount to eat/not to eat something if it is not suitable/eat everyday or occasionally/not eat at all/so from that previously ingested data the user can decide what and how much to eat or not. When the user ate it, the information is kept in history and becomes the basic judgment criteria for the meals eaten after. Thus, this system can be considered to contribute to the "recovery of the right to self-determination" and is expected to help residents to regain confidence by managing their day-to-day intakes.

Then, as the present system has been constructed keeping in mind the assessment capabilities of the original CORPORE, it is also applicable for reverse utilized assessment. Therefore, it can be used not only in Japan. In fact, we asked the original CORPORE development team to trial this system, and it was highly evaluated. It was also announced to be easier to use than the "original CORPORE because it is only necessary to input each dish, and not each food ingredient as originally and this is obviously more realistic for the Japanese context," "Because ETHOS and CORE activities in Belarus started 10 years after the accident, Cs-134 was ignored in CORPORE given its very small influence at the start of the project. In Japan, the accident has just happened so the knowledge about short nuclides in their half-life corresponded to the multi-nuclides is extremely valuable."

Also, it became possible to handle the natural origins of radioactivity information from the previous self, and to perform the management of global radioactivity uptake.

The number of food products is 1,199,241, which is integrated in the product database. The levels of 1,113,931 products of them (92.8 %) are under the detection limit value. Among them the number of food products added from January to March 2015 is 67,401, among them 65,117 (96.6 %) are about the detection limit value or less, equal to or greater than the limit value (Table 20.1) of the food makes 145 (0.2 %) of cases. For the 145 ingredients of the limit value or more see Table 20.2. The percentage of foods with the limit value or more is very little, mostly it is wild boar meat, but because black bear meat and Japanese deer meat is not common in a general household it is hardly applicable as a food ingredient for Japan. It can be said that the majority of Japanese people at the moment are hardly affected by this food. However, easy evaluation tools are required in contaminated areas for evaluation and the understanding of the situation. These tools will help to develop the radiation protection culture to individuals allowing them to have a grip on their own protection.

Table 20.1 The reference levels of foods in Japan (Notice No. 0315 Articles 1 of the Department of Food Safety, March 15, 2012)

Category	Limit level (Bq/kg)
Water	10
Soft drinks	10
Tea for drinking	10
Milk	50
Foods other than above	100

Table 20.2 A breakdown of the products positive at levels exceeding limits between January 1st and March 31st 2015 in the product database

Name of product	Number of products positive at levels exceeding limits
Wild boar meat	116
Japanese deer meat	10
Asian black bear meat	5
Copper pheasant meat	3
Japanese stingfish	3
Iwana mountain trout	5
Landlocked masu salmon	1
Mushroom powder	1
Stone flounder	1

Moreover, these tools are urgently required in this situation, and it is essential to prepare and keep them in order in case of future contingencies.

20.4.2 Subject of Future Investigation

The system is made to favor the development of the radiation protection culture of people in contaminated areas and its neighborhoods; it will be one of the tools of reconstruction of their living environment, so it is necessary to consider this system for the future.

This system estimates the amount (Bq) of radioactivity that was ingested by using the mechanism of CORPORE, visualizes the state of users' history, and helps to show the discharged radioactivity as a graph. However, the residents of contaminated areas want to know how much of the exposure dose (mSv) they receive and the ingestion part of it. In the future, it will be necessary to establish a mechanism for displaying the conversion of the level of contamination (Bq) into the internal dose (mSv) by using a conversion coefficient of each species that is provided by the ingested amount of radioactivity of the ICRP Publication 72 [13].

Although inputting cooking information is available and there are cooking information templates to be obtained from a recipe site to make the input easier, it is still a hard work to manage each meal every day. We want to consider the ways to make this process even easier. For example, we consider making it possible to identify food from a photograph of the cooking or the supermarket receipt and POS information of shopping to guess the food.

For determining the amount of the radioactivity ingested, the food eaten by the user might not be available in the food database, and does not correspond to any food measurement results; even if it is unknown it still may be sufficient. We do not consider the radiation level to be 0 but wait a month and build a graph of the uptake potential calculating it from the maximum value and the minimum value of radioactivity in food of the predetermined period on the food database width, or ingenuity, such as displaying the value of the radioactivity survey conducted before the accident [14]. In this regard we think it is necessary to pursue the reflection on the best way to proceed.

As mentioned earlier, the results for Cs-137 and other nuclide species are not currently integrated into the database structure to correspond to the multi-nuclide variety. This not only concerns nuclides which are listed in the radioactivity measurement results of the MHLW, but also the internal exposure control is possible by ingestion of natural radionuclides by incorporating models such as potassium 40 and polonium 210.

Also, due to the use of a computational model of the original CORPORE calculation system, used in the European context, we would like to consider the comparison method and use of the computational model with accordance to the Japanese data only.

Then, from the original CORPORE development team we receive an opinion that "since the genre of diet became different we want to be able to compare the exposure situations. Separating the diet patterns will help to make groups in the future automatically." For example, seafood diet group, agricultural group, etc. will help to build a kind of patterned templates for further study, and can increase the number of subgroups in each group such as according to gender or regions for future statistical data. In this paper, the system was evaluated by experts. The evaluation by residents is also required to evaluate the actual usability. We intend doing it in the future.

In addition, after the nuclear accident, there was an increasing interest in medical exposure; the efforts have become more active for the medical exposure dose management [15–17]. Also, Dose Structured Report was defined in DICOM as a standard for radiation exposure information management for medical exposure [18], while we are in the environment, which is easy to collect the information of the medical exposure.

As it is described above, in the present situation the influence of internal exposure from food is almost negligible for a large number of individuals although it is of concern for the residents and could be sensitive for specific groups of population consuming home-grown products and products from the forest. The impact of external exposure from the surrounding environment is considered to be potentially larger depending on the area as well as on the individual habits and activities. External exposure data have been gathered in the Prefecture health survey in collaboration with dose assessment [19]. In the future we consider building a system that can manage all the radiation exposures (including medical exposures) of the individual, with the main purpose to develop the radiation protection culture.

In addition, radiation dose information should not only be managed, but also the day-to-day nutrition management and health management could be considered also, with a unification mechanism where individuals can add nutrition information on food. Furthermore, it is expected to be also applicable for the management of the body accumulation of toxics such as arsenic and heavy metals and not only radioactivity.

20.5 Conclusion

Using the tools of the mechanism that has been used for internal exposure assessment in Europe after the Chernobyl nuclear power plant accident, we built a Web application for local residents of contaminated areas suffering from the Fukushima nuclear power plant accident so that they can determine themselves whether or not to eat the food, and use this tool to receive information. The user can input cuisine meals information in food ingredient units in accordance with the Japanese food environment. It is possible to view the quantity of radioactivity ingested and also the history of the internal exposure. It is designed to help to develop the radiation protection culture of residents by capturing the information visually.

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