Comprehensive Evaluation System for ^{137}Cs Migration and Radiation Levels in Eastern Fukushima Prefecture

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INTRODUCTION

The March 2011 accident at Tokyo Electric Power Company's (TEPCO's) Fukushima Daiichi Nuclear Power Station (FDNPS) released large quantities of radio-nuclides into the environment. The most significant contaminant that remains is the radioactive cesium isotope ^{137}Cs, which has a half-life of 30.1 years. Seven years after the accident, people retain concerns about the migration of ^{137}Cs into inhabited areas from forests and contaminated rivers. They are also concerned with the trends of ^{137}Cs concentrations in agricultural, forestry and fishing products.

The Japanese Government is endeavoring to re-open the evacuation zone in stages to allow the return of residents and workers, and the resumption of forestry and paddy farming. Both active and passive radiological countermeasures are being enacted to achieve this goal. Thus, it is important to evaluate the trends of ^{137}Cs concentrations and the re-distribution patterns of ^{137}Cs under natural (ex. typhoon floods) or further anthropogenic perturbations (ex. countermeasures). Such information will allow us to predict radiation exposures to returning residents under different repopulation scenarios.

We have been developing a Comprehensive Evaluation System (CES) to evaluate the long-term environmental effects and dynamics of radionuclides [1]. The system can treat various nuclides but we specifically focus on ^{137}Cs here. The system consists of database and prediction units (Fig. 1), with outputs providing information for local governments and residents.

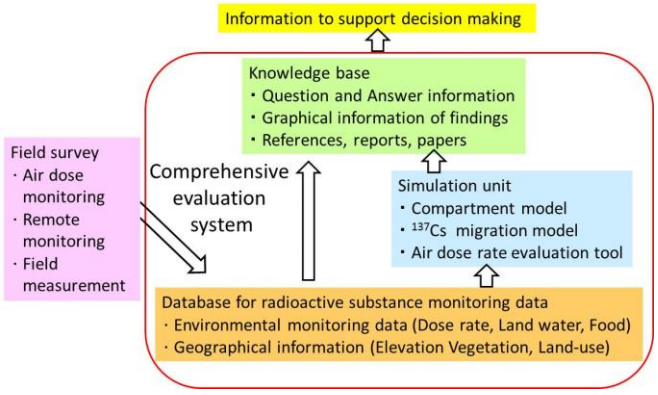

Fig.1 Schematic representation of the comprehensive evaluation system

COMPREHENSIVE EVALUATION SYSTEM

CES consists of three components: a database for radioactive substance monitoring data, a simulation unit, and a knowledge base on environmental remediation.

The database for radioactive substance monitoring data aggregates air dose rate and the radioactivity concentration measurements for various locations.

The simulation unit employs various numerical models to evaluate radioactive material migration and air dose rates under various conditions. A compartment model is used for the evaluation of radioactivity concentrations in agricultural, forestry and fishery products, which are important factors affecting internal radiation exposure. A watershed model is used to evaluate the transport and redistribution patterns of radioactive material on the land surface.

The knowledge base on environmental remediation summarizes research insights, in the form of question statements and plain language answers.

The purpose of the system is to support decision making regarding the resumption of agriculture, forestry and fishing in evacuated zones, planning the reconstruction of affected areas, and rescinding evacuation orders.

Database for Radioactive Substance Monitoring Data

This database [2] contains results relating to the TEPCO FDNPS accident published by various organizations including the Secretariat of the Nuclear Regulation Authority and Fukushima Prefecture.

The data includes measurements of air dose rates, radioactivity concentrations (ground surface, soil, seawater, marine sediment, river water, river sediment, groundwater, and food), stem flow, surface runoff, soil loss and through-fall rates. The database allows intuitive and comprehensible visualization of this data. Data are updated regularly and all entered results are archived in the system.

The database also contains geographical data such as elevation, land-use, vegetation, snow accumulation, and soil types. From the database we can draw up to date monitoring and environmental research results, for example:

- ^{137}Cs discharge from the land surface (forest, etc.) mainly occurs during heavy rainfall periods, but the total discharge per year is lower than 0.1% of the total fallout deposition amount. A portion of the discharged particulate ^{137}Cs accumulates on flood plains but the air dose rates tentatively decrease over time.
- Though the dissolved ^{137}Cs concentration in rivers and reservoirs is below 1 Bq/L, dissolved ^{137}Cs is still discharged from litter layers in forests, and from

particulates in river water and deposited sediment in reservoirs. Therefore long-term monitoring is still needed for evaluating the impact on forestry and fishery.

- ^{137}Cs concentration in deposited sediment in coastal areas is significantly reduced and the number of benthic fish that exceed the reference ^{137}Cs concentration is limited.

Simulation Unit

The system integrates various simulation models to evaluate ^{137}Cs redistribution in Fukushima Prefecture. A compartment model is the high-level code, with various different codes tightly linked around this. The strategy is that the various codes cover different spatial scales and timespans of simulation, providing accuracy where needed. We employ simple, fast, models for quick evaluation of transport over long time periods and large spatial scales. Here we describe examples of two codes.

The compartment model [3] is used to estimate future ^{137}Cs accumulation quantities in each compartment by using data from the field survey database and others. It also estimates changes in ^{137}Cs accumulation amounts with or without different countermeasure scenarios, such as installing silt fences in reservoirs to reduce contamination release downstream. By changing the transfer rates between compartments, we can estimate the resulting inventories of ^{137}Cs and eventually predict contamination concentration in fish, crops, etc.

The Soil and Cesium Transport model (SACT) evaluates soil erosion and sediment-sorbed ^{137}Cs transport [4] using input data from the field survey database. It gives order of magnitude estimates of ^{137}Cs transport on a yearly basis, and evaluates re-distribution patterns of ^{137}Cs. The Universal Soil Loss Equation (USLE) and a Geographical Information System (GIS) underlie the model, which takes a minimum number of hydraulic equations and parameters as inputs. It supports large simulation areas (hundreds of km) and long-time ranges (tens of years) with small calculation costs. We calculated annual discharge quantities and rates for ^{137}Cs through river basins surrounding the FDNPS site and our estimates of ^{137} Cs discharge to the ocean were comparable with estimates based on monitoring data [5].

The results of the simulations, and important new monitoring results, are appended to the knowledge base to provide information for the public and policy makers on risks and countermeasure options.

Knowledge Base on Environmental Remediation

The abovementioned monitoring and simulation results enhance the quality of information regarding the present and future Fukushima environment, and are combined together, described using plain language, and put into the knowledge base on environmental remediation. We arrange the results in a Q & A format using graphs to summarizes the various findings and insights [6] (example shown in Fig. 2).

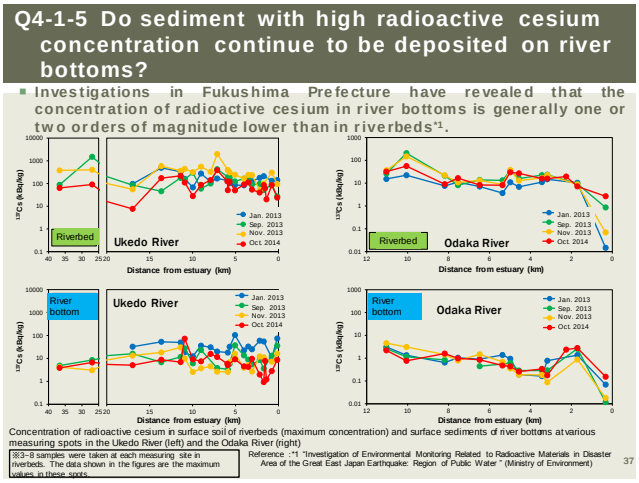

Fig.2 Example of question and answer information from the knowlede base on environmental remediation within CES

By answering questions one by one, the slides provide useful information to people who are concerned with present and future environmental quality in Fukushima Prefecture.

We are now strengthening the integration of the three components of the system to improve the usability of the CES.

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