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Fukushima remediation: status and overview of future plans

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ABSTRACT

The 2011 accident at the Fukushima Dai-ichi Nuclear Power Plant, Japan, released large quantities of volatile radionuclides, requiring evacuation of a 20 km zone around the reactor site plus additional areas where fallout was particularly high. After decay of shorter-lived isotopes, off-site contamination is now dominated by $^{134/137}Cs$, with ~1800 km^2 having external gamma doses above 5 mSv y^{-1}. Although the significance for health of such radiation levels is low, there has been a Government decision that these areas will be cleaned up to reduce exposure and allow displaced residents to return home. After initial tests at 2 sites, a further 11 demonstration remediation projects have been carried out. This work is coordinated by the Japan Atomic Energy Agency (JAEA), with MCM providing support in quality assessment of radioactivity measurements, evaluating the success of different clean-up methods and developing guidelines for the next multi-year phase of large-scale remediation. This work provides a unique perspective on the progress of remediation, experience gained and issues that still need to be resolved – particularly associated with management of the huge quantities of waste generated. This knowledge base will also be important for the bigger challenge of on-site remediation, which will require decades to complete. Additionally, experience and tools may be transferable to cleaning nuclear legacy sites around the world, a problem that is often forgotten in the debate on national nuclear waste management.

1. Introduction

1.1. Background

The chronology of the Fukushima Dai-ichi nuclear power plant (FDNPP) incident is described in detail elsewhere (e.g. IAEA, 2011). In brief, on 11th March 2011, three operating reactors (units 1–3) shut down automatically, as designed, when the magnitude 9.0 (Richter) Tohoku earthquake occurred; the other three reactors on site (units 4–6) were already shut down for routine maintenance. Complete loss of site power, predominantly due to the subsequent tsunami, led to loss of cooling and serious temperature excursions in units 1–3 and fuel storage ponds associated with these units and also with unit 4.

The response to this situation was greatly constrained by the regional devastation caused by the largest earthquake and tsunami experienced in Japan in the nuclear age, which knocked out local power, transport and communication infrastructure, but also diverted emergency response teams to the huge number of human and industrial emergencies that were occurring at the time throughout northeast Japan. Despite this, the seriousness of the situation was communicated to regional and national government, resulting in a series of steps to establish radiological health protection (evacuation from nearest areas, issue of iodine tablets, restrictions on the use of some foodstuffs), while on-site teams fought to cool critical facilities.

Despite heroic efforts, it was required to vent reactor containment as pressures built up due to fuel overheating and eventual melting. This involved the release of gaseous and volatile radionuclides into the atmosphere. Additionally, efforts to cool the reactors and storage ponds led to run-off of contaminated water. Hydrogen resulting from reaction of hot fuel with water caused destructive explosions in Units 1, 3 and 4, which distributed contaminated debris around the site.

Apart from radioactive noble gases, which are generally short lived and disperse without any environmental or human concentration mechanism and hence are of little radiological significance, atmospheric releases were dominated by volatile fission products (predominantly isotopes of I, Cs, Te and, to a lesser extent, Ag). This of course is in marked contrast to the accident at Chernobyl where due to the lack of secondary containment, the entire reactor core (not just the volatiles) was explosively dispersed into the surrounding environment. Of the radionuclides released from FDNPP, the initial

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focus was on radio-iodine, particularly the relatively longer lived ^{131}I (half-life 8 days), due to the potential for concentration in both foodstuffs and the human thyroid. After a few months, however, I-isotopes had decayed to insignificance and the focus of radiological assessment and associated remediation was thus on ^{137}Cs and ^{134}Cs (half-lives approximately 30 and 2 years, respectively).

It was unfortunate however, that immediately after the FDNPP accident, comparisons were made with the Chernobyl exclusion zone. Whilst technical experts were fully aware of the differences between these two accidents (e.g. the fallout from FDNPP was more akin to the Chernobyl fallout received in Scandinavia, NE England and western Scotland, than that in the Chernobyl exclusion zone), these differences were not, however, clearly communicated to the general public – McKinley et al. (2011a).

1.2. Actions taken after the accident

Evacuation areas were originally based on linear distance from the reactor site (eventually set at 20 km), which established an "off limits" exclusion zone. Based on measurements of actual fallout levels, this was extended by a "planned evacuation" zone to the northwest (Fig. 1) of the plant. For about the first 6 months, implementation of an integrated remediation plan was constrained by the requirement to fully stabilise damaged reactors to reduce the risk of further releases of radioactivity, but also by the time required to establish necessary legal structures for actions that were beyond anything covered in previous regulations to cover disaster management.

Nevertheless, this period was utilised to carry out decontamination activities outside the evacuation zones. Local "hotspots" or areas of high sensitivity (e.g. schools) were identified where immediate ad hoc actions were taken to reduce potential doses – predominantly by local groups coordinated at a community or municipality level, with technical support provided by government ministries or specialist organisations like JAEA (Japan Atomic Energy Agency). Such work, which ran in parallel to the first formal planning of regional remediation, was reviewed by an IAEA team who reported positively on progress and made useful recommendations for future actions (IAEA, 2011).

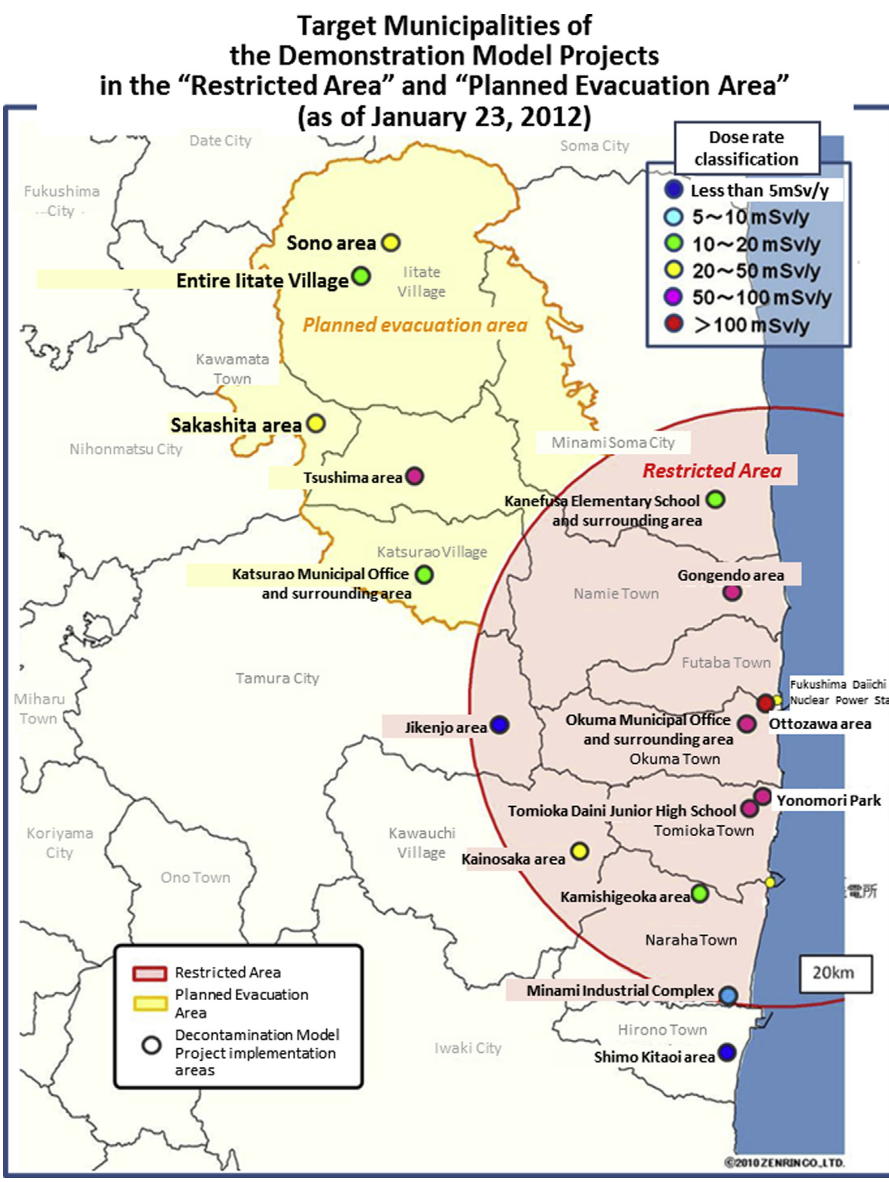

Fig. 1. Map illustrating the evacuation zones. Immediately after the accident a zone of 20 km radius around FDI was evacuated ("restricted area"). After aerial radiation measurements were performed the evacuation was extended to an area northwest of FDI, this is referred to as the "planned evacuation area". Map supplied courtesy of JAEA.