Fukushima and Chernobyl Nuclear Accidents' Environmental Assessments and U.S. Hanford Nuclear Site's Waste Management

Yasuo Onishi[a,b]

[a] Pacific Northwest National Laboratory
[b] Washington State University

Abstract:

This paper describes environmental clean-up activities at Japan's Fukushima Prefecture and a proposed strategic remediation plan. It also discusses the environmental assessment and remediation of the Chernobyl aquatic environment in Ukraine, and the Hanford and Los Alamos National Laboratory sites of the U.S. Department of Energy in the Unites States. The magnitude 9 earthquake and the tsunami damaged northeastern Japan on March 11, 2011. These natural disasters caused Fukushima Daiichi Nuclear Plant's reactor core-melt accident that amounted to approximately 1/7 of the radionuclides released to the environment in the 1986 Chernobyl nuclear accident. These released radionuclides are mostly ^{131}I, ^{134}Cs and ^{137}Cs, with very small amounts of ^{89}Sr, ^{90}Sr, ^{238}Pu, and $^{239\text{-}240}Pu$. Radionuclides released to the environment undergo the transport and fate processes through the following mechanisms:

- Transport of radionuclides by water and air movements.
- Transport, deposition and re-suspension of particulate radionuclides by soil and sediment movements.
- Adsorption and desorption causing radionuclide phase changes between dissolved and particulate forms.
- Radionuclide decay and production of daughter products.
- Radionuclide influx from and efflux to other environmental media (e.g., radionuclide transfer from air to surface soil, from surface soil to groundwater and surface water).

For the Fukushima nuclear accident case, cesium is strongly adsorbed by soil, especially clay and fine silt. Thus, radionuclide adsorption, and subsequent soil erosion and sediment transport, are the main mechanisms to move cesium from one location to another, rather than deposited cesium being transported by groundwater and surface water in a dissolved form. For this reason, cesium deposited on the land from the Fukushima accident has remained mostly on the land surface without significant downward migration toward the water table of the groundwater, making removal of a thin top surface of the affected soil an effective environmental clean-up method. This environmental remediation has been earnestly implemented by the Japanese clean-up teams. However, some cesium deposited in forest areas appears to have migrated downstream by rainwater, eroded soil and fallen leaves carried off by surface runoff.

To prevent or reduce the human exposure to the radiation induced by the nuclear accidents, one can reduce the radiation level in the environment, and/or cut-off radionuclide pathways to humans. In the Fukushima nuclear accident case, a main remediation effort has been to reduce ^{134}Cs and ^{137}Cs concentrations on the land surface by removing or burying contaminated soil, glasses, low branches of trees, and fallen leaves in and around residential and farm areas. The main objective is to reduce the external dosage people receive to live safely in the affected areas. The Japanese government also ensures the safety of foods by preventing foods with a cesium concentration exceeding 500 B/kg from reaching consumers.

A proposed environmental remediation strategic plan for the Fukushima area is to:

- Provide a scientifically valid comprehensive plan for environmental clean-up decision making and for implementation of specific remediation activities in a given contaminated location.
- Promote public participation to remediation decision making by setting up this environmental assessment and clean-up planning system in a webpage.

The proposed strategic plan consists of the following five distribution maps covering the entire contaminated area:

- Environmental parameter distribution maps
- Radionuclide transport parameter maps
- Radionuclide migration and fate rate maps
- Remediation site map with specific remediation technologies assigned
- Remediation priority map.

Whereas the focus of the current Fukushima remediation effort is to reduce the radiation level of the environment, Chernobyl remediation focuses more on disconnecting aquatic pathways contaminated by ^{137}Cs and ^{90}Sr from humans. This is mainly because 20 million Ukrainians consume farm produce produced with Dnieper River's irrigation water. Kiev City also uses the Dnieper River water as drinking water. A successful remediation case was to build dikes along the Pripyat River to isolate highly contaminated floodplains around the Chernobyl Nuclear Plant. The current major Chernobyl remediation activity is to build a 270-m-wide, 144-m-long, and 100-m-high movable structure called New Safe Confinement to cover the current Chernobyl Shelter. Besides alleviating radiation exposure to remediation workers, this structure aims to reduce radionuclide contamination in the nearby groundwater and the Pripyat and Dnieper rivers by eliminating pathways to humans, in case the current Chernobyl Shelter collapses. These Chernobyl remediation activities require the radionuclide migration assessment to determine their effectiveness.

The Hanford Site of the U.S. Department of Energy is located in eastern Washington State along the Columbia River. It had nine nuclear reactors to generate spent fuels and had reprocessed them to produce plutonium. These activities contaminated large amounts of soils, subsurface water, and the Columbia River. Remediation at the Hanford Site includes both reducing radiation levels in the environment and eliminating environmental pathways to humans. Hanford reprocessing activities have also produced 360,000 m^3 of highly radioactive wastes that are stored in 177 underground tanks on the site. These wastes consist of sludge, saltcake, liquid, and gases and are highly basic (pH 10~14). They have high salt content and are chemically and physically very complex. These tank wastes are to be removed from the storage tanks for subsequent vitrification at the Hanford Waste Treatment Plant currently under construction for their final disposal. The site has been undergoing extensive remediation, including dismantling nuclear facilities; removing contaminated soil, cleaning groundwater, retrieving radioactive waste from storage tanks; and treating, storing and disposing the wastes.

This paper describes these various remediation activities under way at the Fukushima accident site, Chernobyl, and Hanford.

The importance of assessing the radionuclide migration in responding to the environmental contamination is also illustrated here by the plutonium migration in forests and in canyons of the Los Alamos National Laboratory Site of the U.S. Department of Energy in New Mexico. Because plutonium is even more adsorbed by fine sediment (i.e., clay and fine silt) than cesium is, soil erosion by runoff water over the land surface, and subsequent in-stream transport, deposition and re-suspension of plutonium-sorbed fine sediments are the most critical phenomena to determine the plutonium distributions on the forest and canyons.