INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

March 2016

Fukushima Daiichi nuclear accident
-
Management of radioactive water from the damaged reactors

Situation in March 2016

This document is based on publicly available information on the situation of the Fukushima Daiichi plant.

I. Background: accumulation and continuous inflow of water into the buildings

During the accident that affected the Fukushima Daiichi nuclear plant on the 11^{th} of March 2011, the natural phenomena that caused it resulted in the flooding of the site, generating an accumulation of water in the basements of the power plant buildings.

In addition, since the accident, water injected for cooling the damaged cores of the reactors has been flowing into the basements of the buildings, from where it is pumped to cool the reactors again, after treatment; Currently, around 325 m^3 of water flow daily into the basements. This water flows into the primary and containment vessels and cools the core. It becomes radioactive by dragging in particular the most mobile elements in the corium. In this regard, while uranium and the transuranic elements are not very soluble, some fission or activation products are more readily dispersible in water (caesium, strontium, antimony, tritium, etc.).

TEPCO has thus found an activity of the order of several GBq/m^3 or tens of GBq/m^3 for caesium in the water accumulated in the basements of the "turbine" buildings. The dose rates in some of the building basements, due particularly to the presence of radioactive water, but also to the reactor circuits located there, can reach a Gray per hour.

Furthermore, the groundwater seeps into the basements increasing the volume of water present (the water inflow is estimated at about 200 m^3 per day). TEPCO indeed keeps the water level in the premises lower than that of the groundwater, thereby limiting the transfer of radioactivity, but also promoting the inflow of water.

Given that the water contained in the basements of buildings is radioactive and that the volumes being added daily are very significant, in the first weeks following the accident their treatment and storage seemed to be important challenges for resuming control of the facilities, in order to control the releases into the environment.

The accumulated volumes (storage tanks and basements of buildings) have now reached nearly 900 000 m^3.

II. Treatment of radioactive water

Water treatment has two objectives: desalination and removal of radionuclides.

Water desalination is necessary, particularly to limit corrosion phenomena: in addition to seawater from the wave that submerged the site at the time of the accident, TEPCO also injected seawater into the reactors to cool them in the days following the accident. Reverse osmosis and evaporation processes were quickly developed and implemented a few months after the March 2011 accident.

TEPCO also desalted the water of the spent fuel pools in which it had also injected seawater.

Furthermore, TEPCO quickly implemented several radionuclide removal systems: three devices were operational a few months after the accident in March 2011. One of them is no longer used because it generated a large volume of radioactive sludge. The two remaining systems only allow a partial removal of the radionuclides contained in the treated water, essentially caesium. TEPCO gradually added strontium processing modules to them.

TEPCO has also developed a system for a more complete treatment, which it calls "multi-nuclide removal equipment" or "advanced liquid processing system" (ALPS). This system consists of three subsystems with a capacity for treating 250 m^3/day. Tests in actual configurations were carried out during the second quarter of 2013 and the system proved to be very efficient in decontaminating for all radionuclides present in the water except for tritium. Indeed, to date no industrial means capable of extracting tritium from the water exists. After having encountered various problems during the testing phases, the ALPS entered its industrial operation phase in November 2013.

TEPCO strengthened its water treatment capacity with the construction, during 2014, of a second similar ALPS unit and a "high performance" ALPS unit equipped with a line allowing the treatment of 500 m^3/day.

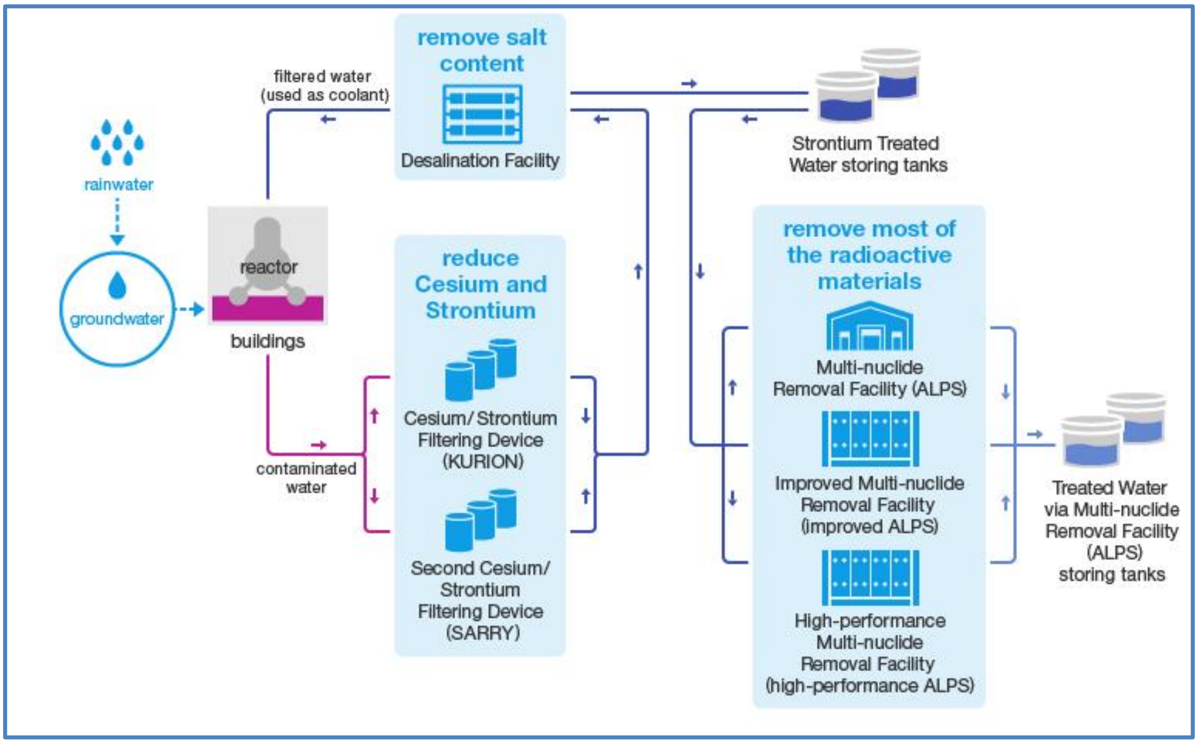
In addition, to treat the water already stored, TEPCO has deployed two new mobile strontium treatment systems, called "Kurion Mobile Processing Systems" (KMPS), with a processing capacity of 300 m^3/day, which were commissioned in October 2014 and in February 2015.

It should be noted that TEPCO also set up a system for the treatment of the groundwater after it is pumped[1] and before its release: this system has two lines with a capacity to process 1 200 m^3/day.

The year 2015 was a major milestone for TEPCO in terms of water decontamination. Since May 2015, all of the water stored has undergone treatment, either complete by one of ALPS systems (around 600 000 m^3 of water stored to date), or to remove caesium and strontium before future complete treatment (around 150 000 m^3 of water stored to date)[2].

The waste from the treatment processes (resins, zeolites, etc.) have led to the filling of nearly 3 000 containers of radioactive waste, which are stored at the site.

The figure below gives an overall view of the treatment chain for the water from the Fukushima Daiichi reactor buildings after the commissioning of all of the systems.



Source TEPCO - General path of the water accumulated at Fukushima Daiichi

[1] See the information note regarding the site groundwater for the objectives of this pumping.
[2] Only a few thousand m^3 of water pass, without having undergone complete treatment, into buffer tanks prior to their injection into the reactors.

III. Water Storage

Water treatment is only a first step towards managing the water accumulated on the site. Indeed, it is necessary for TEPCO to obtain authorisations for the release of treated water still containing residual radioactivity (mainly tritium).

In the meantime, **TEPCO should store ever increasing volumes of water.** The combined current storage capacity is now about 1 000 000 m^3.

In order to meet the growing need for storage capacity, TEPCO has implemented all types of storage: vertical tanks with bolted flanges, welded horizontal or vertical tanks, welded cubic tanks, underground tanks, etc., on available land within the perimeter of site. Since 2013 it has also made many improvements to the radioactive water storage means and conditions by learning from various events of varying importance.

These events had multiple origins, due both to the design of the first equipment used (leaks in the flanged tanks, valve failure, overflows, etc.) and to the work being performed at locations that were prepared in an emergency (lack of retention, soil settlement, lack of isolation of the rainwater collection network, etc.).

TEPCO now prefers the construction of welded tanks and has begun the gradual dismantling of tanks assembled with bolted flanges. It has also initiated a vast retention area renovation and improvement programme.

These developments, combined with the tightening of surveillance, have significantly improved the site water storage management.

Source TEPCO – 1) cubic welded tanks – 2) vertical tanks assembled with bolted flanges and welded horizontal tanks – 3) welded vertical tanks – 4) underground tank

Source Google - Storage areas of the water accumulated at Fukushima Daiichi

In conclusion, the storage of contaminated water remains an important issue for TEPCO, since TEPCO should rapidly increase its storage capacities while simultaneously achieving the complete treatment of the stored water. This topic will remain an important challenge, until TEPCO is able to release the treated water. However, the very drastic reduction of the radioactivity contained in the water thanks to the treatments carried out, combined with improved storage facilities (tank design, retention barriers, monitoring) allow better management of this water.

Furthermore, their treatment generates large volumes of secondary waste in addition to those generated by the storage of rubble or the dismantling of the damaged facilities. The operational management of such waste on the site is an important challenge, both in terms of safe sustainable storage and of further processing.