IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

French version : 9 July 2013
English translation : 7 August 2013

Fukushima Daiichi nuclear accident

Management of contaminated water from the damaged reactors

Situation as of end June 2013

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

I. General context: a build-up and a continuous influx of water in the buildings

The natural phenomena that led to the accident that affected TEPCO's Fukushima Daiichi nuclear power plant on March 11th, 2011 also led to flooding of the site leading to an accumulation of water in the basements of the power plant buildings. Furthermore, since the accident, the water used to cool the damaged cores of the reactors has been flowing into the basements of the buildings from where it is pumped in order to be re-used, after treatment, to cool the reactors. As things stand, more than 350 m^3 of water is entering the basements on a daily basis. This water circulates in the reactor vessel, the confinement vessel and the torus, and cools the degraded nuclear fuel. It picks up radioactivity, particularly by leaching of the most mobile elements still contained in the corium. In this respect, although uranium and transuranian elements have very limited solubility, certain fission or activation products are more easily dispersible in water (caesium, strontium, antimony, tritium, etc.). TEPCO thus reports a caesium 137 activity of the order of several GBq/m^3 in the water that has accumulated in the basements of unit 1 and 2 "turbine" buildings. The dose rates in some of the building basements, due in particular to the presence of contaminated water but also to the reactor circuits installed in these basements (such as the torus), can reach one Gray per hour.

Furthermore, water from the groundwater is penetrating the basements, thereby contributing to the increase of amount of accumulated water. TEPCO is maintaining the level of water in the basements slightly below the groundwater level, which limits the transfer of contamination but favours the influx of water. However, this slight difference limits the flow, which has nevertheless been evaluated at several hundreds of m^3 a day. Finally, rainwater also contributes to the build-up of water in the buildings.

Since the water contained in the basements of the buildings is contaminated and since the amount of water entering them is very considerable (currently estimated to be at least 700 m^3 a day, taking the cooling water and the influx of natural water together), its treatment and storage have become important challenges, since the first weeks following the accident, as regards regaining full control of the facilities in order to limit releases into the environment. The importance of these challenges only increases as time goes by as the accumulated water amount has now reached several hundreds of thousands of m^3.

II. Water treatment

Treating the water has two objectives: desalination and the removal of radionuclides.

- **Desalinisation of the water is necessary**: the wave that submerged the site when the accident occurred was composed of seawater, and TEPCO also injected seawater into the reactors to cool them for several days following the accident. A reverse osmosis process was developed and put in place very quickly a few months after the accident.

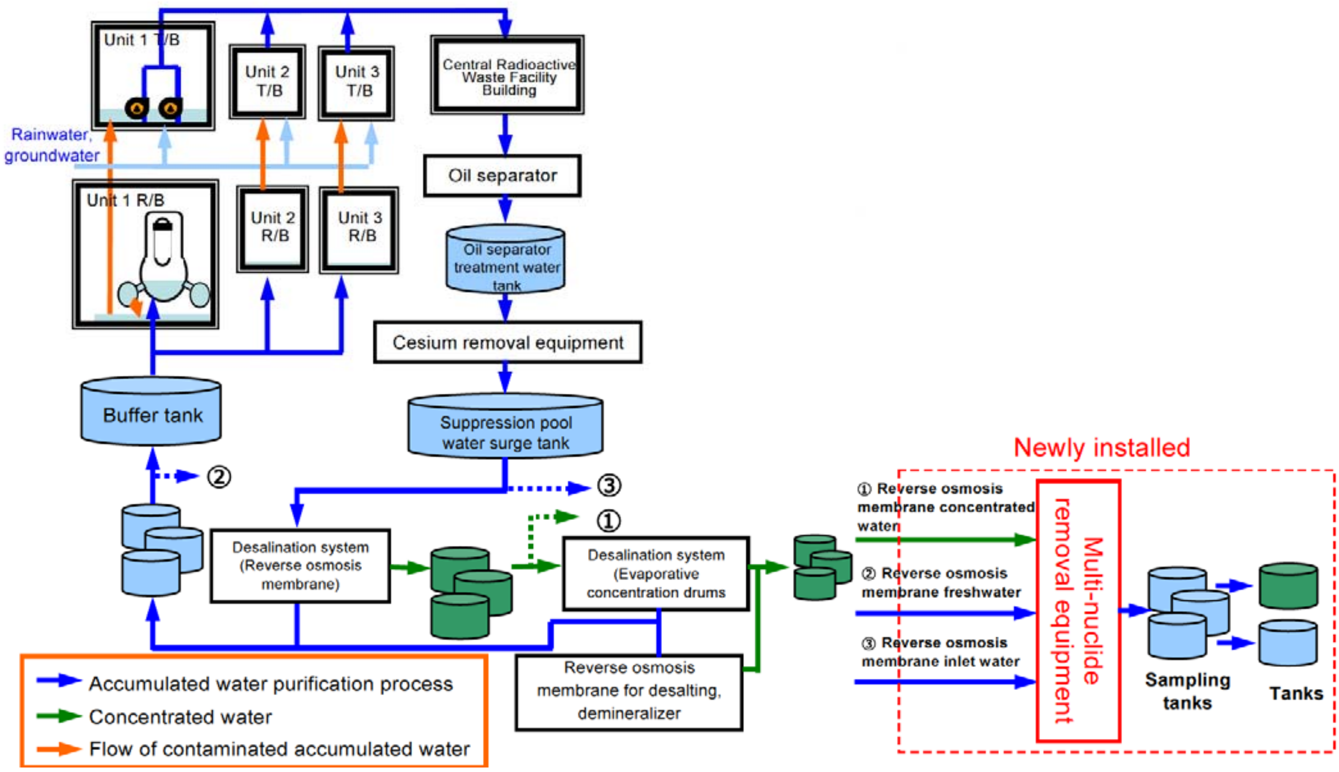
It should be recalled that TEPCO also had to desalinate the water of the spent fuel storage pools of reactors 2, 3 and 4, into which seawater was also injected. This operation is currently completed.

- **As with desalination, TEPCO also quickly implemented an initial method for removing radionuclides.** It has called on external contractors, notably French, whose expertise enabled operational equipment to be made available a few months after the accident. These measures allow partial removal of the radioelements contained in the treated water.

TEPCO then launched the development of a second system enabling a complementary treatment, which it has called a "multi-nuclides removal equipment" (the ALPS facility). This system comprises three equivalent sub-systems, each with a unit treatment capacity of 250 m^3/day. The hot testing began in the second quarter of 2013 and are still on-going. TEPCO envisages the full scale operation of this water treatment system in the course of the second half of 2013.

According to TEPCO, the order of magnitude of the volume of water treated since the accident is some 700,000 m^3.

The figure below gives a synthetic view of the complete treatment chain of water from the Fukushima Daiichi reactor zones following commissioning of all the various systems.



Source TEPCO – General block diagram of the routing of water accumulated in Fukushima Dai-ichi

TEPCO is regularly improving the water treatment equipment in order to take into account the lessons that have been learned from various incidents that have occurred, e.g. by increasing the number of pumps to improve reliability, replacing flexible piping by rigid piping in order to reduce the risks of leakage or modifying the control of valves in order to be able to control them remotely.

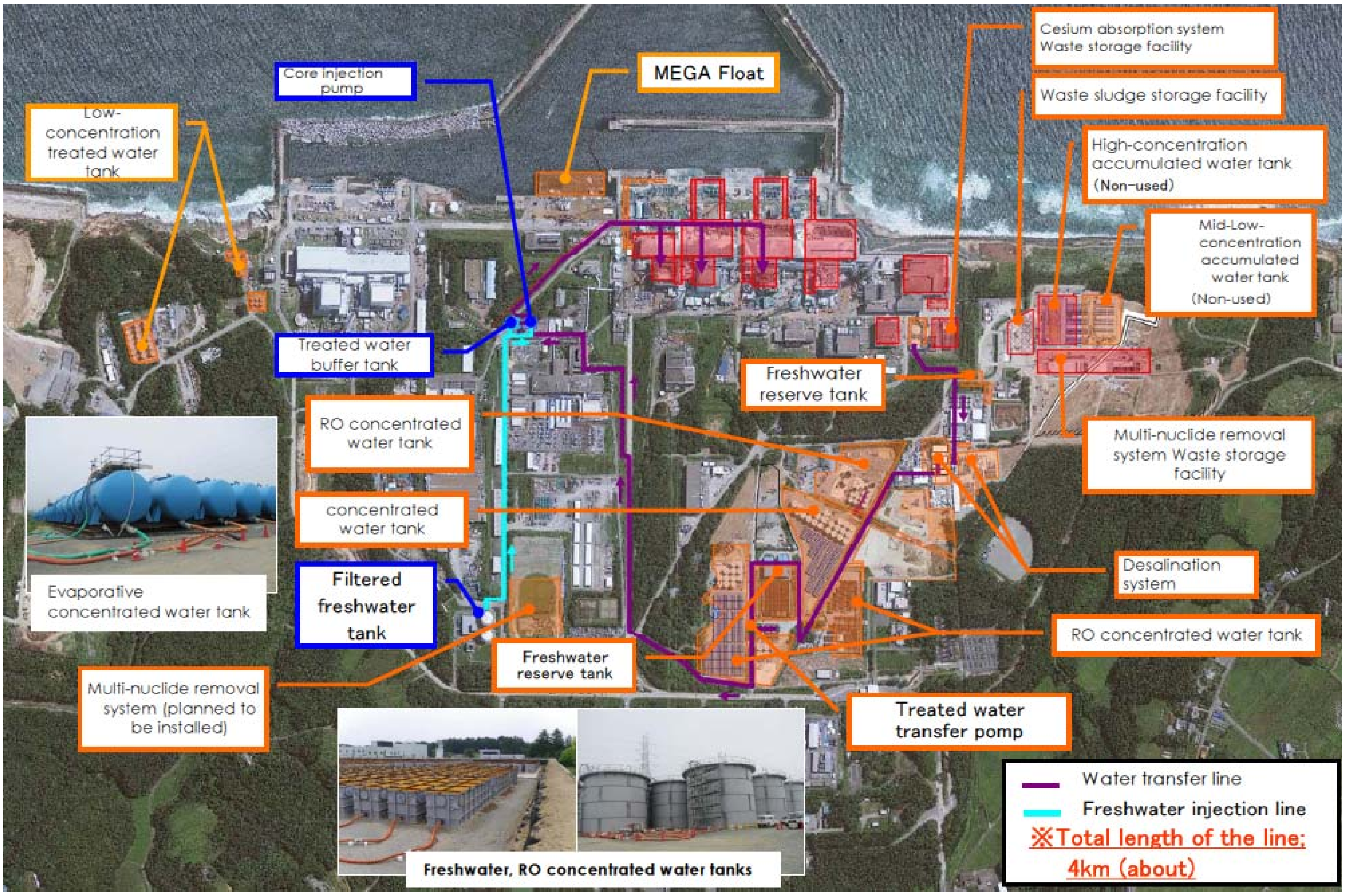
Finally, **the design of the ALPS system takes account in particular of the difficulties encountered with current treatment systems:** installation of leak detectors and a retention system surrounding the facility, insulation of equipment to protect them from freezing, use of rigid pipes, specific training of operators, etc. TEPCO is also carrying out long term tests in order to detect potential defects. As an illustration, some defects have been recently identified on a tank welding.

III. Water storage

Water treatment is only the first step in the management of the water that has accumulated on the site. In fact, firstly the removal of radionuclides is still only partial, as mentioned above and, secondly, even when all of the systems have been in operation, it would be necessary for TEPCO to obtain authorisations to release the treated water, which would still contain residual radioactivity.

In the meantime, **TEPCO has to store increasing volumes of water.** At the end of March 2013, TEPCO thus announced a storage capacity of 325,000 m^3 with an objective of 450,000 m^3 by mid-2013 and, beyond that, a capacity of some 700,000 m^3 by mid-2015.

TEPCO has put in place various types of storage facilities, as shown in the image below, which also indicates the location of the treatment systems.



Source TEPCO (January 2013) – Location of accumulated water storage zones in Fukushima Daiichi

Once again, the particularly difficult context has meant that TEPCO has not been able to install and operate these water storage facilities without encountering problems of leak tightness from time to time, such as the leak that recently affected the underground reservoirs in April 2013.

IRSN points out that, notwithstanding the difficulties of storing the accumulated water, its treatment generates waste, such as sludge containing extracted radionuclides, the management of which constitutes a major challenge, not only in terms of safe long term storage but also subsequent conditioning. TEPCO has already defined actions in this respect. For example, what are known as "high integrity" containers are planned for the waste from the ALPS facility and a research programme is scheduled. Whatever the case, the information available concerning these subjects remains less detailed than information relative to less pressing issues.