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IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

# BRIEFING NOTE

DATE: **21/04/2021**

## Radioactive waste resulting from the Chernobyl accident
## Review – March 2021

The accident which occurred on 26 April 1986 at the Chernobyl NPP's Reactor 4 resulted in a massive release of radioactive material into the environment in the form of gases, fuel particles, and aerosols. The hasty decontamination work around the damaged power plant generated large quantities of radioactive waste (nearly two million cubic metres of plants, soil, construction materials, various equipment, etc.) which were disposed of in the exclusion zone around the damaged reactor.

Waste was managed according to its radioactivity. Intermediate and high level waste ($10^4$ Bq/g to above $10^6$ Bq/g) was mainly stored in concrete casemates (Podlesny facility, for example, see Figure 1) or disposed in sealed-bottom trenches covered with a clay layer (Buriakovka facility, see Figure 1). Both types of facility are subject to radiation monitoring. Their characteristics and the inventories of the waste they contain are presented in Table 1, and their location is indicated in Figure 2.

*Figure 1: Podlesny (left) and Buriakovka (right) facilities.*

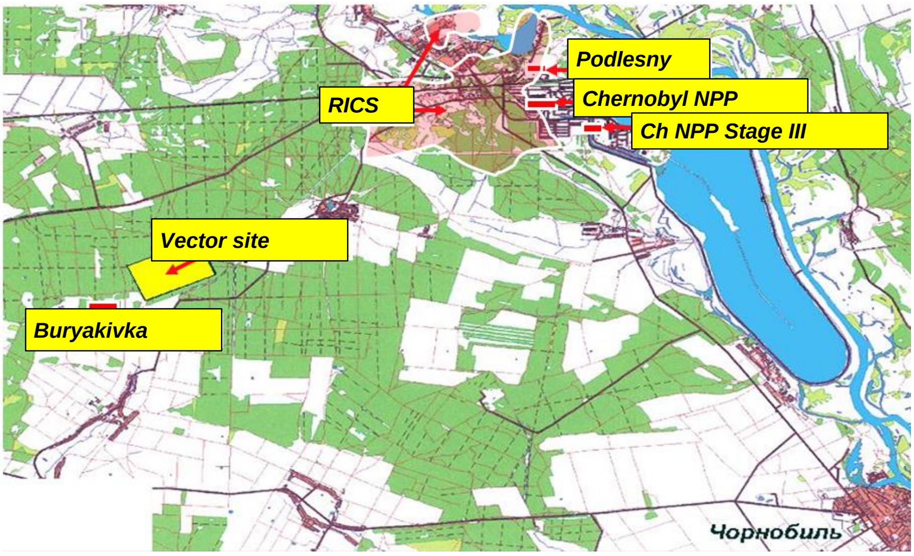


*Figure 2: Map of the various interim storage and final radioactive waste disposal sites in the exclusion zone.*

*Table 1: Waste treatment facilities for radioactive waste exceeding $10^4$ Bq/g.*

| **Facilities** | **Characteristics** | **Types and volume of waste** | **Radiological inventory** |
|---|---|---|---|
| Buriakovka disposal | Disposal in sealed-bottom trenches covered with a layer of clay, operated since 1987 | 700,000 $m^3$ of intermediate-level waste | 2.6 $10^{15}$ Bq<br>(Cs, Sr, Eu, Pu, Am) |
| Podlesny storage | Storage in concrete casemates, operated between 1986 and 1988 | 11,000 $m^3$ of remediation waste generated following the accident (high-level and long-lived waste) | 2.6 $10^{15}$ Bq<br>($^{137}$Cs, $^{90}$Sr, $^{134}$Cs, $^{154}$Eu, $^{155}$Eu, $^{238}$Pu, $^{239,240}$Pu, $^{241}$Pu, $^{241}$Am) |
| ChNPP stage III storage, also called Kompleksny | Storage in concrete buildings, operated between 1986 and 1988 | 26,000 $m^3$ of remediation waste generated during the emergency phase (low- and intermediate-level and long-lived), some of which is encapsulated in metal drums | 2.8 $10^{14}$ Bq<br>($^{137}$Cs, $^{90}$Sr, $^{238}$Pu, $^{239,240}$Pu, $^{241}$Pu, $^{241}$Am) |

Work has recently been carried out on these facilities. For example, a new water drainage system and eight new groundwater monitoring wells were built around the Podlesny facility in 2012, and, in 2018-2019, additional characterisations were undertaken to specify the radiological and physical characteristics of the waste. New engineered barriers were built on the ChNPP stage III facility and the monitoring system was upgraded in 2016. Finally, the Buriakovka trench disposal facility reached its initial capacity (30 trenches) and an authorisation was issued in 2019 for the construction of six new trenches.

Further waste treatment facilities are under construction at the Vektor site in the exclusion zone. This is a used sealed source and solid radioactive waste storage facility intended to receive waste from the Chernobyl NPP currently in operation as well as from other Ukrainian power plants.

Two other facilities, in the 10 km zone around the Chernobyl NPP, are under construction for the dry storage of spent fuel assemblies from VVER-1000 and VVER-440 reactors (16,529 fuel assemblies) and for the storage of high-level vitrified waste from the reprocessing of spent fuel assemblies in Russia.

Low- and intermediate-level waste (between $10^2$ and $10^4$ Bq/g), consisting of contaminated soil, wood, and construction materials, was stored as tumuli or, most often, buried in trenches located on nine sites within a radius of 10 km around the damaged reactor (Yaniv Station, Naftobaza, Pischane Plato, Rudyy Lis, Stara Budbaza, Nova Budbaza, Prypiat, Kopachi, and Chystohalivka). These nine sites, called 'Raw Interim Confinement Sites' (RICS), are located in the areas shaded pink in Figure 2. Thus, from 1986 to 1987, between 800 and 1,000 trenches were dug in the sand soil and covered with a 20 to 50-cm layer of sand. These trenches are generally 2 to 4 m deep, a few metres wide, and a few hundred metres long. It is estimated that one million cubic metres of radioactive waste are buried in them, representing a total radioactivity of $2.10^{15}$ Bq.

Various works are in progress in these trenches, including census operations to identify the locations of the trenches and waste inventories, as well as maintenance operations. Some trenches, those posing the most risk to workers in the exclusion zone and to the environment, have been emptied. In 2020, 7,700 $m^3$ of waste was removed from the trenches and disposed of at the Buriakovka facility, among others.

Most low-level waste trenches are not airtight or do not have an effective barrier against the migration of radioactive pollutants; as such, a gradual migration of radionuclides into the groundwater was detected from the 1990s.

IRSN research on the mobility of radionuclides in soil and groundwater on these sites, carried out from 1999 in cooperation with Ukrainian institutes (IGS[1], UIAR[2]), focused on an instrumented trench on the Rudyy Lis site (trench T22 of the EPIC pilot project - Experimental Platform in Chernobyl), located 2.5 kilometres west of the damaged reactor (see Figure 3 and Figure 4). All the data acquired was used as input for models simulating the transfer of $^{90}$Sr to groundwater by considering different flow conditions (Bugai et al., 2012a; Nguyen, 2017). Estimated $^{90}$Sr migration speeds were one metre per year in the 1990s which decreased to a few tens of centimetres per year in the 2000s. However, these models fail to reflect some activity measurements made in groundwater. The impact of seasonal phenomena on the main processes governing the transfer of $^{90}$Sr to groundwater could be significant, in particular on the percolation of water through the trench and on the horizontal movements of water at the base of the trench in connection with piezometric fluctuations in the groundwater. The presence of $^{90}$Sr in the vegetation on the site also indicates a transfer of $^{90}$Sr from the soil to the vegetation, which could explain certain variations in $^{90}$Sr activity observed in the groundwater.

Other observations and studies show that plutonium migrates through groundwater at a rate similar to that of strontium. $^{137}$Cs, on the other hand, is very slow, due to its attachment to the substrate, only travelling at a speed of less than one centimetre per year. However, plant roots do manage to capture some of this fixed $^{137}$Cs, as has been observed and quantified.

Thus, the T22 pilot site appears particularly suitable for studying the activity evolution in this type of trench in the face of climate change and/or changes in cover due to (i) a characterised

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[1] Institute of Geological Sciences

[2] Ukranian Institute of Agricultural Radiology

source term; (ii) a less complex and widely described hydrogeological context; and (iii) marked transient phenomena over a relatively short period.

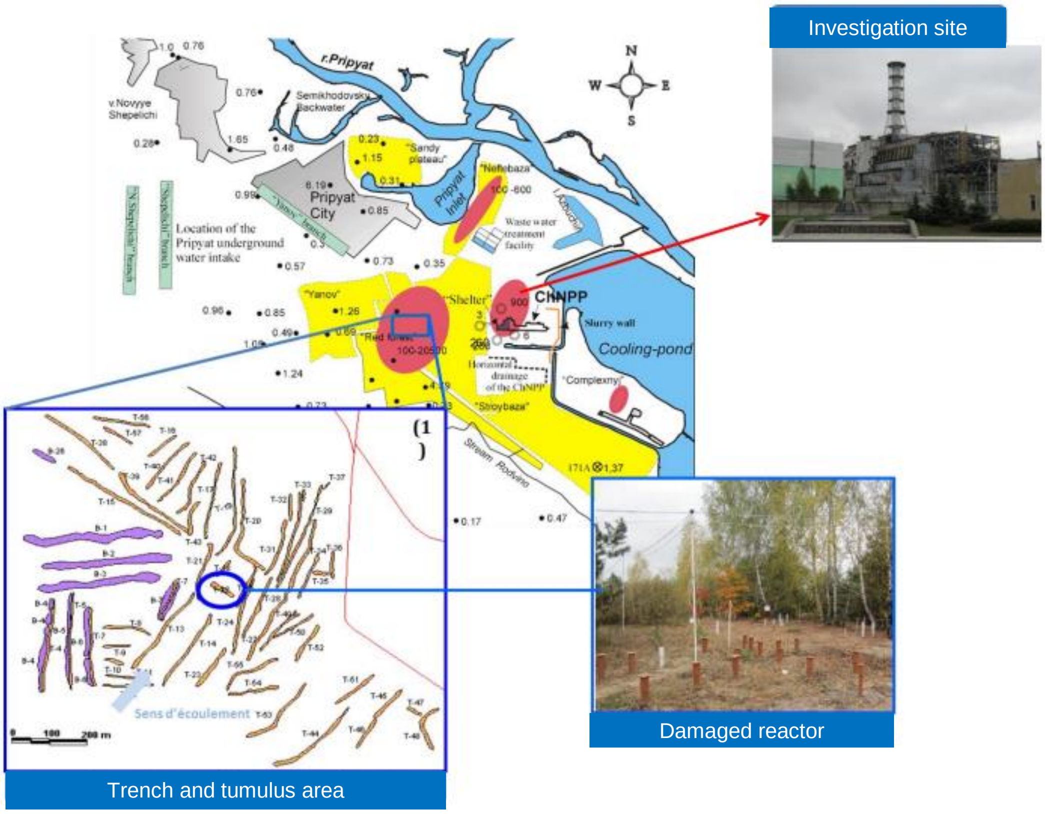


*Figure 3: Location of the trench T22 site (investigation site).*

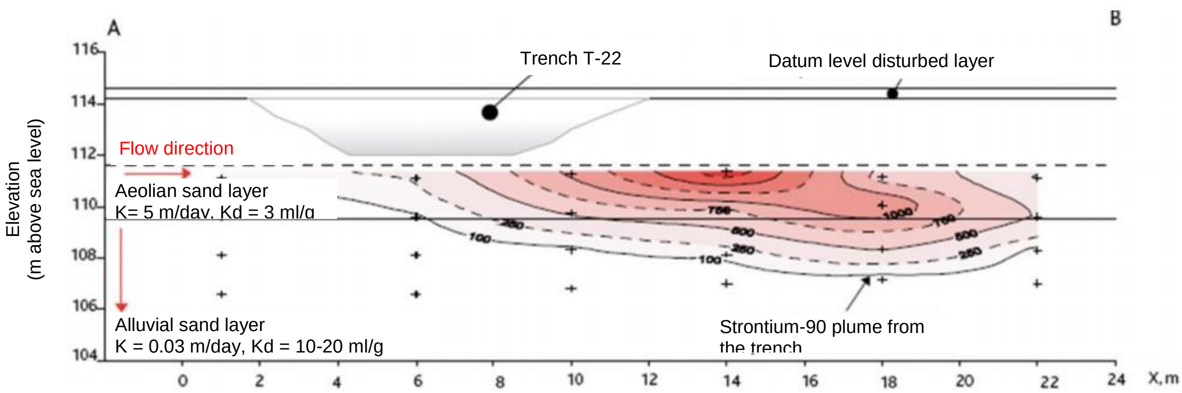


*Figure 4: Cross section of trench T22 and extension of the $^{90}Sr$ plume in the groundwater.*