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IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

BRIEFING NOTE

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Large fires in the Chernobyl region
Origins and environmental consequences

Since the nuclear accident that occurred on 26 April 1986 on Reactor 4 at the Chernobyl NPP, the environment near the plant has been very heavily contaminated over areas of approximately 2,600 km^2 in Ukraine and 2,400 km^2 in Belarus that are still prohibited today (exclusion zones).

These areas, which were partially cultivated or forested at the time of the disaster, have largely been abandoned. As a result, the vegetation and forests have continued to grow and develop to the detriment of cultivated areas. Despite the efforts, made by the countries most affected by the fallout from the accident, to limit this phenomenon, the state of the forest is deteriorating, giving way to the accumulation of dead plants and densifying biomass. This deterioration of the forest, together with climate change marked by a more intense and earlier dry season, increases the risk of fire, and certain agricultural practices (burning) intended to eliminate dead vegetation in the spring, regularly cause fires. Arson, electrical accidents, and lightning (although to a lesser extent) are the other main causes of fire.

Local and regional fires and plumes

The ecosystem close to the Chernobyl NPP has regularly suffered from major fires: about ten since 1992. The magnitude of these fires depends on several factors including, as mentioned above, vegetation density, shrub and tree species (heather, pine, birch, oak, aspen, alder, beech, etc.), land use, meteorological conditions (humidity, drought, wind, and precipitation), and the capacity to fight against their spread. The surface areas concerned vary from one fire to another (from a few tens of km^2 to nearly 900 km^2, as in 2020).

2002 was a particularly damaging year for the wilderness areas (forests and peatlands) in the Moscow region and, especially, in Ukraine. During the summer of 2002, over 60,000 hot spots were detected in a vast area encompassing Eastern Europe, Belarus, Ukraine, and the western part of the Russian Federation. According to the State Emergency Service of Ukraine (SESU), the first three months of 2020 were characterised by a 30% increase in the number and severity of fires. It was precisely in April 2020 that the worst forest fires ever recorded in the Ukrainian region around the Chernobyl NPP occurred.

In temperate regions of the northern hemisphere (latitudes between 30 and 60°), the general circulation of tropospheric air masses is west to east. Therefore, the smoke plumes that develop in the eastern part of Europe generally tend to disperse towards the east and the Eurasian continent. However, in high-pressure conditions, continental air masses can move towards Western Europe. The combination of a high-pressure situation and a major fire in contaminated areas remains relatively rare but has repeatedly caused the dispersion of an ash plume containing artificial radioactive material detectable in traces in several European countries, as was the case in August and September 2002, March 2003, early August 2010, and, more recently, in April 2020.

The great fire of April 2020

At the beginning of April 2020, forest fires started to rage in the north of Ukraine, in particular in the area most contaminated by the fallout from the accident at the Chernobyl NPP. The fires spread for about four weeks, penetrating the Chernobyl Exclusion Zone (CEZ) coming close to the NPP and radioactive waste storage facilities. The fires were eventually extinguished by sustained rainfall which significantly helped firefighters contain the fire. According to the Ukrainian Hydrometeorological Institute (UHMI), approximately 870 km^2 (87,000 ha) were destroyed, of which 65 km^2 in the immediate vicinity of the NPP and another 20 km^2 on the left bank of the Pripyat river. Forest fires can emit large quantities of artificial radionuclides (^{137}Cs, ^{90}Sr, plutonium isotopes, and ^{241}Am) into the air. These radionuclides are mainly contained in surface soil layers, forest litter, and, to a lesser extent, in biomass.

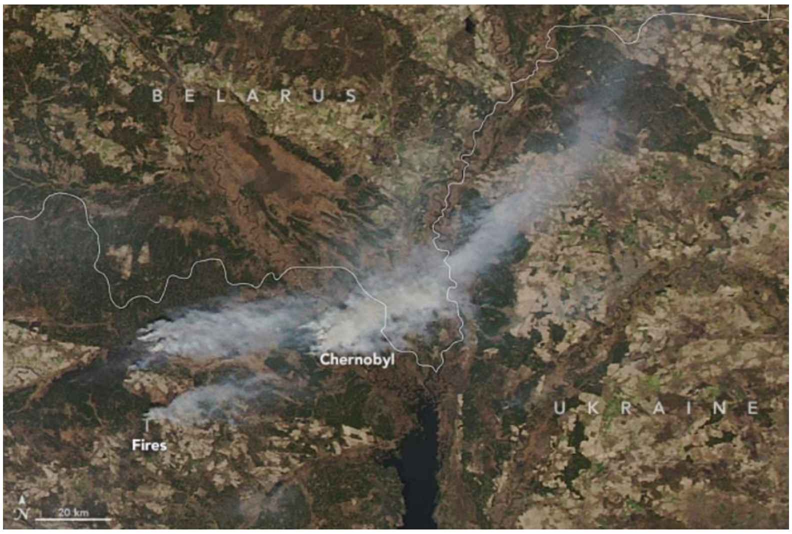

Figure 1: Satellite image of the fires in the Chernobyl region on 9 April 2020. Photo credit: NASA Earth Observatory images, Lauren Dauphin. Use of MODIS data from NASA, EOSDIS/LANCE and GIBS/Worldview. https://earthobservatoryr.nasa.gov/images/146561/fires-burn-in-northern-ukraine.

Figure S2: Cumulative representation of active fire detections from MODIS and VIIRS satellite data between 1 April and 1 May 2020. Data source: NASA/FIRMS (Fire Information for Resource Management System). The Chernobyl nuclear power station's location is marked with a yellow star.

Estimation of the quantities of remobilised radionuclides

The duration of the episode (> 4 weeks) caused abundant plumes which generally drifted eastwards but also several times towards southern and western Europe. The radioactivity of these plumes was widely measured, in particular that of cesium-137 which emits radiation that is more easily detectable than other artificial radionuclides like Pu, Sr, and Am. Based on the 1,200 measurements of airborne ^{137}Cs concentrations in Europe communicated by nineteen of its European counterparts, the IRSN was able to evaluate, using atmospheric dispersion models (inverse modelling), the quantity of ^{137}Cs emitted by the fires (source term). This was estimated to be around 0.7 to 1.2 TBq for all outbreaks. As no concentration of ^{90}Sr or plutonium was measured in the air outside of Ukraine, the same methodology could not be used to estimate the source term of these radionuclides. However, around forty measurements of ^{90}Sr activity concentrations and around thirty of plutonium in the air, carried out in the Chernobyl exclusion zone, were reported. The ratio of these concentrations to those of Cs-137 measured in the same area as well as the use of characteristic ratios of the Chernobyl accident made it possible to extrapolate the orders of magnitude of the amount of Sr, Pu, and Am remobilised by the fires. A ^{90}Sr source term two times weaker than that of ^{137}Cs, around 480 GBq (range between 345 and 612 Gbq), was estimated. For plutonium isotopes and ^{241}Am, the source terms estimated by the IRSN were respectively 1.5 GBq for ^{238}Pu and ^{239}Pu, 2.2 GBq for ^{240}Pu, 59.0 GBq for ^{241}Pu and 21.7 GBq for ^{241}Am.

Assessment of radiological consequences

The IRSN carried out a dosimetric evaluation on two categories of people: firefighters who fought the fires in the exclusion zone and the inhabitants of Kiev (about 100 km to the south). The inhalation dose was assessed taking into account a deliberately aggravating approach including the following assumptions: 1) the firefighters did not have respiratory protection 2) a total working time in the exclusion zone of around one hundred hours for each of them (ten days at the rate of ten working hours per day), 3) a respiratory rate of 3 m^3/h corresponding to very intense physical effort during firefighting (CIPR 66), 4) all the emitted aerosols in the respirable fraction. The atmospheric concentrations considered were mainly estimated using the measurements taken on filters sampled in the field for which ^{137}Cs, ^{90}Sr, ^{238}Pu, and $^{239+240}$Pu were simultaneously measured. The estimates of activity concentrations of ^{241}Pu and ^{241}Am were deduced from the ^{241}Pu/$^{239+240}$Pu ratio characteristic of the fallout from the Chernobyl accident, taken from literature[1], taking into account the radioactive relationship between ^{241}Pu and ^{241}Am.

From the highest concentrations measured in the air (around 1 Bq.m^{-3} for ^{137}Cs and ^{90}Sr, 1 mBq.m^{-3} for ^{238}Pu), the dose potentially received by a firefighter due to the inhalation of radioactive smoke would have been at most 170 microSievert (µSv) in total, of which around 80% was solely due to ^{241}Am. This result is probably overestimated since it was also assumed, for the purposes of the calculation, that the maximum concentrations observed over very short periods (half an hour, for example) lasted a hundred hours. A more realistic dose assessment can be made based on the spatially and temporally averaged concentrations found within the exclusion zone during the fires. In this case, the resulting dose induced by inhalation of all the artificial radionuclides considered in this study over a period of a hundred hours would be 1.3 µSv (or 0.0013 mSv).

Despite the relative significance of the maximum ^{137}Cs concentration measured in the vicinity of the fires (0.2 Bq/m^3), dosimetric evaluations indicate that the contribution of ^{137}Cs to the inhalation dose remains negligible compared to that due to ^{90}Sr, Pu isotopes, and especially ^{241}Am. In addition, most of the dose (all exposure routes combined) is attributable to external exposure by radionuclides deposited in the environment near the Chernobyl NPP in April and May 1986. This external exposure results from the presence of firefighters in this highly contaminated area and is not directly related to the fires. Based on data published in the literature, external exposure due to the contaminated environment is between 0.1 and 1 mSv for a presence of around a hundred hours in the Chernobyl exclusion zone. By way of comparison, the current limit imposed by Ukrainian regulations for personnel working in the Chernobyl exclusion zone is 3 mSv/year.

The dosimetric impact of the fires for Kiev inhabitants, taking into account the inhalation of particles and the consumption of foodstuffs contaminated by atmospheric deposition of radioactive particles, remained very low. The effective dose for an adult has been estimated at 0.150 µSv resulting mainly from inhalation (0.1 µSv for inhalation from 1 to 22 April 2020 and 0.050 µSv for ingestion over a period of one year after deposit). Americium 241 alone represented about 75% of this inhalation dose, followed by plutonium isotopes (~ 25%), the contribution of ^{137}Cs and ^{90}Sr being around 1%. To calculate the ingestion dose, the main agricultural products considered included seasonal vegetables (April), dairy products, and meat. A daily consumption of 500 g of leafy vegetables was used as the worst-case scenario. As confirmed by Talerko et al. (2021), the dose induced by external exposure to the fire plume (immersion) was negligible compared to internal exposure via inhalation. Total exposure therefore remained well below the annual public exposure limit of 1 mSv according to the Ukrainian radiation protection standards for the public as an added effective dose (NRBU-97, 2000) or compared to the global annual average exposure of 2.4 mSv induced by natural radiation (UNSCEAR, 2000).

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[1]The activity concentrations obtained were: 1 mBq/m^3 for ^{239}Pu, 1.5 mBq/m^3 for ^{240}Pu, 44 mBq/m^3 for ^{241}Pu, and 12 mBq/m^3 for ^{241}Am

In the rest of Europe and particularly in France, the dosimetric impact by inhalation and ingestion of foodstuffs on which minute amount of radionuclides from these fires may have been deposited was negligible.

For more information:

- https://www.irsn.fr/fr/actualites_presse/actualites/pages/20200505_ni-tchernobyl-ukraine-incendies-zone-exclusion-synthese-des-consequences.aspx#
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