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Near-field krypton-85 measurements in stable meteorological conditions around the AREVA NC La Hague reprocessing plant: estimation of atmospheric transfer coefficients

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ABSTRACT

The aim of this work was to study the near-field dispersion of ^{85}Kr around the nuclear fuel reprocessing plant at La Hague (AREVA NC La Hague – France) under stable meteorological conditions. Twenty-two ^{85}Kr night-time experimental campaigns were carried out at distances of up to 4 km from the release source. Although the operational Gaussian models predict for these meteorological conditions a distance to plume touchdown of several kilometers, we almost systematically observed a marked ground signal at distances of 0.5–4 km. The calculated atmospheric transfer coefficients (ATC) show values (1) higher than those observed under neutral conditions, (2) much higher than those proposed by the operational models, and (3) higher than those used in the impact assessments.

1. Introduction

Predicting the dispersion of accidental radioactive releases into the atmosphere and estimating their radiological consequences for the population are a major challenge for organizations involved in nuclear safety. Countries and institutions have therefore developed many (more or less operational) dispersion models, each of which has its own spatio-temporal scale. The Gaussian models are still used for near-field applications, particularly in the case of emergencies due to their simplicity and calculation speed. During emergencies situations, it must be possible to provide information to the authorities in few minutes often with very little data on the release and the weather conditions. The first types of information that are available are (1) the position and height of the release point, (2) the velocity and direction of the wind, which are measured in real time on sites, and (3) an idea of the atmospheric stability, which depends primarily on the wind speed, time and meteorological conditions (cloud cover, rain, etc.). In such situations, the Gaussian models are used first, followed by finer modeling approaches a few hours later. In France, IRSN's *centre technique de crise* (emergency response center) uses the C3x operational platform (Isnard, 2006), which includes the pX and ldX dispersion models. ldX ise a large-range Eulerian atmospheric dispersion model (Quélo et al., 2007), while pX is a short-range (up to a few tens of km) Gaussian puff model (Soulhac and Didier, 2008; Mathieu et al., 2012; Korsakissok et al., 2013). Simulations performed with pX are based on the Pasquill, Briggs or Doury standard deviations (Pasquill, 1961; Doury, 1972; Briggs, 1973, 1985). Other countries also use Gaussian puff models, such as the RIsø-Mesoscale-PUFF (RIMPUFF) model (Mikkelsen et al., 1984) or the HOTSPOT Gaussian plume model (Homann and Aluzzi, 2013), which was developed by the U.S. Department of Energy and is designed to quickly estimate the radiological impact of short-range (less than 10 km) atmospheric releases. ADMS (Atmospheric Dispersion Modeling System) is used by the Met Office and the U.K. Government (CERC, 2010), and AERMOD (Aerodynamic Modeling System) is now the official standard in the U.S. (Tartakovsky et al., 2013; Rood, 2014). These models, usually assessed against the "model validation kit" (Olesen and Chang, 2010) have rarely been compared to a complete set of experimental data for stable atmospheric conditions, in the near field, primarily because of the difficulty of conducting this type of experiment. However, light winds and stable situations can be very frequent (more than 50% of the time) in some areas. Fully understanding dispersion in these areas

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is a major challenge since the pollutants travel slowly and populated areas near the emitting source will be affected the most.

The AREVA NC La Hague site in northwestern France is one of the world's largest fuel reprocessing plants. It is located in a topographically complex area (near the ocean and cliffs). During reprocessing operations, the plant's two 100-m-high stacks emit krypton-85 (^{85}Kr), a radioisotope that can be measured in the environment (Ahlswede et al., 2013). Krypton-85 is a chemically inert radionuclide with a half-life of 10.71 years. It decays by β^- emission ($\beta^- = 687.4$ keV, >99%) followed by a low γ decay branching ratio (514 keV at 0.43%). IRSN has been conducting experiments with ^{85}Kr at the La Hague site for many years (Gurriaran et al., 2004; Maro et al., 2002, 2007. Leroy et al., 2010; Rennesson et al., 2005; Connan et al., 2011a, 2013).

To better understand the mechanisms of near-field atmospheric dispersion for elevated releases around the La Hague plant, obtain experimental data and compare these data to the operational models, IRSN carried out a first set of experimental campaigns under neutral conditions in 2001–2002 (Pasquill stability class D). The light winds in stable meteorological conditions are harder to study and at the time no confirmation data was available for stable conditions E and F according to the Pasquill classification. However, although these conditions are not the most common at the La Hague site, they do occur around 15% of the time.

The aim of this work was therefore to (1) conduct near-field experimental campaigns in stable situations around the AREVA NC La Hague site, (2) compare the results obtained with the data provided by the operational models used for accident situations in France by focusing on stable meteorological conditions, and (3) compare the experimental values of the atmospheric transfer coefficients (ATC) obtained with those used to calculate the dosimetric impact to populations.

2. Materials and methods

2.1. Characteristics of the industrial site and the ^{85}Kr release

The nuclear fuel reprocessing plant, AREVA NC La Hague, is located on the La Hague peninsula in northwestern France. This narrow (5 km wide) and slightly hilly peninsula is characterized by steep cliffs at the southern end of the site. The area consists primarily of moorland and hedgerows. The facility rises to a height of 180 m above sea level and is located, along the prevailing wind direction, 1.2 km from the southwestern coastline and 3.5 km from the northeastern coastline (Fig. 1). The industrial site is 2 km long by 500 m wide and is characterized by a dense conglomeration of buildings as much as a few tens of meters high. It has two production units (known as UP3 and UP2-800) located 200 m apart. Each unit is equipped with a 100-m-high stack. During nuclear fuel reprocessing, ^{85}Kr is discharged into the atmosphere for periods of 30–45 min. During our study, data on the ^{85}Kr release fluxes (time step = 10 min) were provided by AREVA NC.

2.2. Description of a dispersion campaign

2.2.1. Preparation of a campaign

The desired stable meteorological conditions occur around 15% of the time, which is little considering that although the plant must be operating at all times, it is shut down several times each year. Over a 3-year period, the weather forecasts issued by Météo France (France's national meteorological service) were monitored in order to anticipate a period during which an experimental campaign could be conducted. In addition to the meteorological forecast data, two ultrasonic anemometers (Young, 81,000 V) were used between April 2010 and September 2013 (Fig. 1). One was installed at a height of 30 m at the plant (49,682247°N, −1,893186°W) and the other was installed 2 km north of the site in an open area and at a height of 10 m (49,695004°N, −1,873246°W). The data recorded by the anemometers were sent in real time to the laboratory located 18 km away, in the town of Cherbourg-Octeville, over a 3G network using a modem and the VNC Viewer software. The conditions we set for being able to start an experimental campaign were working at night (1 h after sunset) with a negative sensible heat flux H and a positive Monin–Obukhov length of 0–200 m and light winds of less than 5 m s^{-1} at a height of 10 m. The decision to start a campaign was made based on the weather forecasts (issued the previous day) and observations (made 1 h beforehand). If the forecasts called for a probability of light winds and a clear night sky, a preliminary alert was issued and the necessary staff was placed on standby. Conducting a dispersion measurement campaign required a staff of five, a mobile laboratory and two vehicles for transporting and positioning the sampling systems. The morning before a night that potentially met all the conditions, AREVA NC was contacted to make sure that the plant would be conducting shearing operations and that ^{85}Kr would be released during the night. Between 7:00 p.m. and 9:00 p.m., the person in charge of monitoring the weather logged on to the two ultrasonic anemometers and make sure that the sensible heat flux H became negative and that the LMO was between 0 and 200 m with a clear night sky. When these conditions were met, the team went to the plant between 8:00 p.m. and 10:00

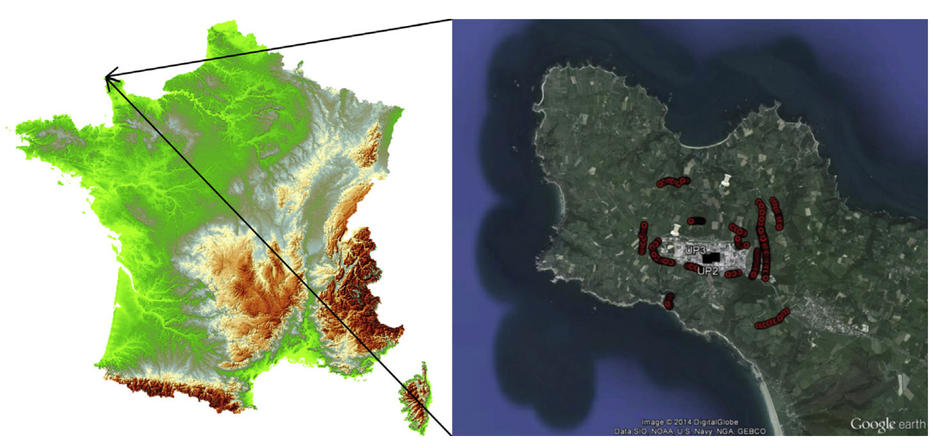

Fig. 1. Experimental area for the dispersion campaigns. In black UP3 and UP2-800 stacks of the nuclear fuel reprocessing plant AREVA NC; in white, position of the two ultrasonic anemometers, in red, positions of sampling locations.