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Comparative assessing for radiological, chemical, and physical exposures at the French uranium conversion plant: Is uranium the only stressor?☆

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Abstract

This study presents the pattern of exposure to uranium and other occupational pollutants known to be potentially carcinogenic, mutagenic or toxic and used at the main uranium conversion plant in France. For different uranium compounds specified according to their solubility and purity, and 16 other categories of pollutants: chemicals, fibres, vapours, dust, and heat a time- and plant-specific job exposure matrix (JEM) was created covering the period 1960–2006. For 73 jobs and for each pollutant the amount and frequency of exposure were assessed on a four-level scale by different time periods. The JEM shows 73% sensitivity and 83% specificity. Although exposure assessment was semi-quantitative, the JEM allows computing of individual cumulative exposure score for each pollutant across time. Despite the predominant natural uranium compounds exposure, the amount of exposure to other pollutants such as TCE and other chlorinated products, asbestos, and fibres, is important at the plant. Numerous correlations detected between uranium compounds exposure and exposure to chemicals warrants improving biological monitoring of exposed workers and accounting for associated exposures in epidemiological studies. Results of this study will be used for further investigation of association between exposure and mortality among uranium conversion workers cohort.

Keywords: Job exposure matrix; Nuclear industry; Uranium; Chemicals; Internal contamination; Exposure assessment

Introduction

Uranium is known for its chemical and radiological toxicity after acute exposure. But there is little evidence on the adverse health effects and particularly on the

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carcinogenic potential of protracted uranium exposure. Cohort studies of workers in the nuclear industry stand out from all other epidemiological studies carried out at the workplace owing to the accuracy of the available exposure data. However, these data are often restricted to external radiation exposure (X- and gamma rays, beta particles or neutrons) for which external dosimetry became systematic for potentially exposed workers as of the early 1950s. Through this monitoring, epidemiologists can use personal irradiation data to determine the risks of occurrence of cancer or non-tumorous pathologies as a function of total received dose during professional life (Cardis et al., 2005, 2007; Guseva Canu et al., 2008c; Rogel et al., 2005; Telle-Lamberton et al., 2004; Telle-Lamberton et al., 2007; Vrijheid et al., 2007). Workers are, however, exposed not only to radiation, but also to other types of pollutant such as chemicals, particle pollutants or asbestos, most of which are carcinogenic. This simultaneous presence of several types of exposure has been described in uranium workers (Guseva Canu et al., 2008a) and is probably significant in many fuel cycle facilities.

With the exception of radiation, direct monitoring of such exposure began relatively recently, as it responds to fresh knowledge in toxicology and to new regulations that also came into effect only very recently (EC, 1998, 2004). It can therefore be assumed that exposure to these factors was greater in the past than now and that new tools, encompassing all types of exposure, whether nuclear, physical or chemical, are required to estimate the risk of cancer and non-tumorous pathologies in workers in the nuclear industry.

Medical records are the main instrument used for monitoring nuclear workers. They include a job description giving details of all types of exposure concerned. Usually, however, different types of exposure are only monitored and documented in medical records in strict accordance with regulatory requirements, while radiotoxicological and whole-body monitoring data on workers only concern exposure to ionising radiation. Furthermore, it is difficult to use these data in epidemiological studies because the medical records of workers in the nuclear industry in France are not computerised and access to them is restricted. Lastly, it is not always feasible to consult medical records for cohort studies as some cohorts may be made up of several thousands of individuals.

Some tools have been developed to overcome these difficulties and some of them take into account some forms of radiation exposure (Boice et al., 2006; Carpenter et al., 1987, 1988; Eheman and Tolbert, 1999; Krishnadasan et al., 2007, 2008; Ritz, 1999; Ritz et al., 1999, 2000, 2006; Rooney et al., 1993; Ruttenber et al., 2001a, b; Wing et al., 1993). One such tool is the job exposure matrix (JEM), which is based on a definition of jobs and the related forms of exposure and includes an assessment of exposure levels (Goldberg et al., 1993; Hoar, 1983). The JEM has sometimes been used in the nuclear field and has provided initial data on some groups of workers (Boice et al., 2006; Carpenter et al., 1988; Eheman and Tolbert, 1999; Henn et al., 2007; Krishnadasan et al., 2007, 2008; Ritz, 1999; Ritz et al., 1999, 2000; Rooney et al., 1993; Ruttenber et al., 2001a, b; Wing et al., 1993). Publications, however, rarely develop information on how these matrices are built or on exposure results, even though such information is crucial for a clear understanding of the environment under study or for a correct interpretation of analysis results. Analysis of the literature (Boice et al., 2006; Carpenter et al., 1988; Eheman and Tolbert, 1999; Henn et al., 2007; Krishnadasan et al., 2007, 2008; Ritz, 1999; Ritz et al., 1999, 2000; Rooney et al., 1993; Ruttenber et al., 2001a, b; Wing et al., 1993) (see summary in Table 1) shows that there are only a few matrices – limited to the description of two or three types of exposure – that are relatively well described and that provide more precise exposure indicators based on measurement data or allow an estimation of cumulated exposure. These are not exhaustive, however, and exclude other types of exposure also found in the workers' occupational environment.

The objective of this study is to investigate exhaustively the exposure to different occupational pollutants at the main uranium conversion plant in France.

Material and methods

The AREVA NC uranium conversion plant in Pierrelatte

The AREVA NC plant in Pierrelatte is located in the south-east of France. It occupies a nuclear production site originally created by the CEA (the French atomic energy commission) in 1960, with a view to building a uranium isotope separation facility for making weapons-grade uranium. The *Compagnie Générale des Matières Atomiques* (COGEMA, which became AREVA NC in May 2006) has been enriching and converting uranium for industrial use since 1976. It is made up of several production facilities, support and maintenance facilities and storage areas. Each facility consists of one or more units and carries out an independent and specific uranium processing activity. Fig. 1 shows how various successive activities have been carried out on the site over the years.

Specific job exposure matrix (JEM) elaboration

The overall procedure is described in Fig. 2. Exposure to uranium-bearing and other chemical compounds used