ARTICLE IN PRESS

International Journal of Hygiene and Environmental Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Prenatal exposure to lead in France: Cord-blood levels and associated factors: Results from the perinatal component of the French Longitudinal Study since Childhood (Elfe)

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ARTICLE INFO

Keywords:
Cord-blood lead levels
Exposure
Environment
Mother-baby pairs
Pregnancy

ABSTRACT

Background: As a result of the ban on lead in gasoline on 2nd January 2000, the French population's exposure to lead has decreased in recent years. However, because of the acknowledged harmful cognitive effects of lead even at low levels, lead exposure remains a major public health issue. In France, few biomonitoring data are available for exposure to lead in pregnant women and newborn. The purpose of the perinatal component of the French human biomonitoring (HBM) program was to describe levels of various biomarkers of exposure to several environmental pollutants, including lead, among mother-baby pairs. In this paper, we aimed to describe the distribution of cord blood lead levels (CBLL) in French mother-baby pairs, and to estimate the contribution of the main lead exposure risk factors to these levels.

Method: A total of 1968 mother-baby pairs selected from the participants of the perinatal component of the French HBM program were included in the study on lead. Lead levels were analyzed in cord blood collected at child delivery by inductively coupled plasma-mass spectrometry (ICP-MS). The data collected included biological sample, socio-demographic characteristics, environmental and occupational exposure, and information on dietary factors.

Results: CBLL were quantified for 99.5% of the sample. The CBLL geometric mean was 8.30 µg/l (95% CI [7.94–8.68]) with a 95th percentile of 24.3 µg/l (95% CI [20.7–27.1]). Factors significantly associated with CBLL were tap water consumption, alcohol consumption, shellfish consumption, vegetable consumption, bread consumption, smoking, and the mother being born in countries where lead is often used.

Conclusion: This study provides the first reference value for CBLL in a random sample of mother-baby pairs not particularly exposed to high levels of lead (24.3 µg/l). A substantial decrease in CBLL over time was observed, which confirms the decrease of exposure to lead among the general population. CBLL observed in this French study were in the range of those found in recent surveys conducted in other countries.

1. Introduction

Lead is a toxic heavy metal widely dispersed in the environment. After absorption, it is stored in the human body (mainly in bones) and has adverse effects on health (Casas and Sordo, 2006). Many studies have detailed the toxic effects of lead including anemia, neuropathy, renal disease and reproductive impairment (Buser et al., 2016; Inserm, 1999; Inserm and InVS, 2008; Neugebauer et al., 2015; Staessen et al., 1996; Wilhelm et al., 2010). The general public may be exposed to lead from numerous sources, including contaminated air, water, soil and food. Contamination of drinking water may occur through plumbing elements containing lead such as solder, pipes, pipe fittings and sediment (Ineris, 2003; Ineris, 2003; Ninosh, 1972). Food contamination with lead from solder may occur during the food production processes, specifically through contact with metal packaging (Crinnion, 2010). Some food products are reported to contain high lead concentrations, such as shellfish and chocolate (Anses, 2011). Taking into account the frequency of consuming foods, the main contributors to lead exposure are bread, alcohol and vegetables (Anses, 2011). Lead-based paint dust may also be a source of lead exposure for general population. Although, the use of white lead for residential construction was banned in 1909 in France (Markowitz and Rosner, 2000), this date was pushed back

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https://doi.org/10.1016/j.ijheh.2018.01.007
Received 8 September 2017; Received in revised form 22 December 2017; Accepted 10 January 2018

Please cite this article as: SAOUDI, A., International Journal of Hygiene and Environmental Health (2018), https://doi.org/10.1016/j.ijheh.2018.01.007

because of the First World War and the consequent industrial intensification. It was only in 1948 that white lead was totally banned for all professional use, thus leading to the almost total disappearance of white lead used to paint walls inside buildings (Rainhorn, 2013). Accordingly, renovation or remodeling of homes built prior to 1948 can generate substantial amounts of lead-containing dust (scraping/sanding activities or painted component removal) and are a potential source of lead exposure, especially for children. Leisure activities (for example, painting) and certain cultural-related practices, including the use of alternative medicines or herbal remedies, the importation of cosmetics, and working with traditional lead glazed pottery, are also major contributing factors to lead exposure among the general public (Bakhireva et al., 2013; FUSSLER, 2011). Moreover, lead is used in a variety of industries (smelting, battery making, paint scraping, shipbuilding, soldering, stained glass manufacture, and brass and bronze foundry work), creating the potential for work-based exposure or exposure for those residing in the vicinity of industries or lead-polluted sites. Workers and their families may also be exposed to lead dust if it is carried home from the workplace on clothing, shoes, or on the body (Bonberg et al., 2017; Hipkins et al., 2004).

In recent decades in France, intensive actions directed at primary prevention have been taken to further reduce lead exposure from gasoline, paint, solder and other sources. As a result, lead exposure from food intake has been declining since the 1980s (Bierkens et al., 2011). Nonetheless, it remains an important environmental health issue in France. Lead exposure affects persons of all ages. In pregnant women it is of particular concern as the metal is able to cross the placental barrier and affect the developing fetus during pregnancy (European Food Safety Authority (EFSA), 2010; Gulson et al., 1997; Mushak, 1998). Moreover, a remobilization of lead accumulated in bones from historic exposure is likely to occur during pregnancy, due to the demand for calcium from within the fetal compartment or because of physiological stress induced by pregnancy (Gulson et al., 2004; Hertz-Picciotto et al., 2000). Breastfeeding is also known to remobilize lead accumulated in the bones and can be a source of exposure for breast-fed infants (European Food Safety Authority (EFSA), 2010; Gulson et al., 1997; Mushak, 1998).

In France, few biomonitoring data are available to estimate lead exposure among mother-infant pairs. The main objective of the perinatal component of the French human biomonitoring (HBM) program was to describe internal concentrations of environmental contaminants among mother-infant pairs, including cord blood lead levels (CBLL). An additional objective was: to identify and quantify the determinants of exposure. This paper describes the distribution of CBLL among French mother-baby pairs and their children and quantifies the influence of known risk factors of lead exposure.

2. Materials and methods

2.1. Study design

The perinatal component in the cohort Elfe[1] (the French Longitudinal Study since Childhood) is part of the French HBM program. This program was established in line with the French Grenelle Law for the Environment (n°2009-967 of August 3, 2009), and in the 2nd and 3rd French National Environmental Health Plans (2009–2013, 2015–2019). The objectives of the program were drawn up by a steering committee including Santé publique France, the French Health and Environment ministries and other French Public Health Agencies. The HBM program was designed to provide a national representative estimation of the population's exposure to various chemicals present in the environment (including food) and to study the determinants of exposure. The perinatal component of the French HBM program is based on a random selection of mother-baby pairs enrolled in the Elfe cohort. To participate in perinatal component, mothers had to have given birth in one of the 211 maternity units located in continental France which participated in the biological data collection process. These units were chosen in such a fashion as to guarantee a degree of regional representativeness of all women who gave birth in continental France in 2011. More details on the study design of the perinatal component are available in (Dereumeaux et al., 2016).

The protocol for the Elfe cohort was approved by several national bodies, including the national data protection authority (National Commission for Data Protection and Liberties), the national statistics body (National Council for Statistical Information), and the national committee for the Protection of Persons.

2.2. Study population and inclusion criteria

The study population included mothers (> 18 years) who had given birth to one or two living babies, after 33 weeks or more of gestation, in one of the 211 maternity hospitals participating in the biological data collection process throughout continental France. The mother-infant pairs were enrolled between the 27th of June 2011 and the 4th of July 2011, or between the 27th of September 2011 and the 4th of October 2011, or between the 28th of November 2011 and the 5th of December 2011. In order to be included in the cord-blood lead level study, mother-infant pairs had to give their consent to provide biological samples and to have a cord-blood sample available for lead analysis.

2.3. Sampling plan

A two-degree probability sampling design was used for the perinatal component of the French HBM program. As mentioned in previous publications (Dereumeaux et al., 2016), in the first stage, the primary sampling units (PSUs) were maternity hospitals selected to participate in biological collection within the framework of the Elfe cohort (n = 211). In the second stage, all eligible mother-infant who attended these maternity units were included at childbirth.

For the analysis of CBLL, a subsample of participants was drawn from mother-infant pairs who agreed to participate in the biological component of the Elfe cohort. The number of mother-infant pairs per maternity stratum was chosen in order to preserve the original distribution according to the institution type (private/public), authorization type (depending on the number of births per year), and geographical area (5 regional clusters) of the maternity unit. A total of 1968 mother-infant pairs were included in the descriptive statistical analyses of CBLL (Fig. 1).

Fifteen percent (n = 295) of the sample selected were excluded from multivariable statistical analyses because they refused to participate in the 20-year follow-up outlined in the Elfe cohort and accordingly, over time, we would have lacked the information needed to estimate retrospective exposure to lead.

The weighting process was conducted in three steps as follows: we first calculated the initial weighting due to sampling. Initial weights were then adjusted to account for non-response observed at each degree. This was done using a score method (Haziza and Beaumont, 2007). Finally, these adjusted weights were calibrated in order to reflect the distribution of the study population. Data from the civil status register and the French National Perinatal Survey of 2010 (Blondel and Kermarrec, 2011) were used for calibration. Calibration was performed with CALMAR software (Deville et al., 1993).

2.4. Data collection

The data collected comprised a dietary intake description, data from biological samples, socioeconomic and demographic information and data form complementary specific items relative to the environment, professional activity, leisure activities and medical characteristics. all

[1] http://www.elfe-france.fr/index.php/en/.