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Blood and urinary levels of metals and metalloids in the general adult population of Northern France: The IMEPOGE study, 2008–2010

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ABSTRACT

Background: The assessment of human chemical risks related to occupational or environmental exposure to pollutants requires the use of both accurate exposure indicators and reference values. The objective of this study was to evaluate the blood and urinary levels of various metals and metalloids in a sample of adults aged 20–59 years of the general population of Northern France, a formerly heavily industrialised area that retains some industrial activity.
Methods: A cross-sectional study was conducted between 2008 and 2010, enrolling 2000 residents of Northern France. The quota method was used to guarantee the representativeness of the participants on a sex, age, social category and smoking status basis, according to the census done by the French National Institute of Statistics and Economic Studies. The levels of 14 metals: aluminium (Al), antimony (Sb), total arsenic (As), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), thallium (Tl), vanadium (V) and zinc (Zn) were quantified by ICP-MS in urine and blood samples.
Results: A total of 982 men and 1018 women participated, allowing the analysis of 1992 blood and 1910 urine samples. Some metal(loid)s were detected in over 99% of the blood (Cd, Co, Mn, Ni, Pb) and urine (As, Co, Pb, Zn) samples and the remaining metals in 84–99% of the samples, with the exception of blood V (19%), blood Be (57%) and urine Be (58%). Mean blood levels of Pb and Zn were significantly higher in men, and Mn, Co and Cr in women. In urine, mean Pb, Tl and Sb concentrations were significantly higher in men, and Al and Co in women. Current smokers had significantly higher mean levels of blood Cd and Pb and lower blood Co, Mn and Hg. In urine (adjusted on urinary creatinine), the smokers had higher mean levels of Cd, Pb, V and Zn and lower mean levels of As, Co, and Hg. Overall, the mean urinary levels of most metal(loid)s found in the general population of Northern France were higher than those found in the French national survey for the same period except for urinary V. Mean blood lead level was markedly less than that of the French national population.
Conclusion: This first biomonitoring survey of a large number of metal(loid)s in the general population of Northern France provides useful information on exposure levels to toxic elements and highlights the specificity of the regional environment. These data could be used, in complement to the national human biomonitoring reference values, for the interpretation of biomonitoring results.

Abbreviations: Al, aluminium; Sb, antimony; As, arsenic; Be, beryllium; Cd, cadmium; Co, cobalt; Cr, chromium; Hg, mercury; Mn, manganese; Ni, nickel; Pb, lead; Tl, thallium; V, vanadium; Zn, zinc; ICP-MS, inductively coupled plasma mass spectrometry; CRI, collision reaction interface; AM, arithmetic mean; GM, geometric mean; [95% CI], 95% confidence interval; P95, 95th percentile of distribution; NHANES, National Health and Nutrition Examination Survey; ENNS, National Nutrition and Health Survey; CDC, Centers for Disease Control and Prevention; ARS, French Regional Health Office; INSEE, French National Institute of Economic Statistics and Studies; B&D, Becton Dickinson; LOD, limit of detection; LOQ, limit of quantification; IUPAC, International Union of Pure and Applied Chemistry.

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1. Introduction

The use of biological exposure indicators has developed greatly over the last few decades, in particular in the context of the biomonitoring of exposure in the workplace, but also to assess the levels of environmental pollutants in the general population. Thanks to the determination of the chemical substances themselves or their metabolites in biological liquids, human biomonitoring enables an assessment of the exposure to chemical substances whatever their sources (e.g. workplace, food, home, tobacco smoking) and the entry pathways (respiratory, digestive and cutaneous) (Angerer et al., 2007). The levels measured are not only useful for assessing exposure and following up the levels in the populations over the course of time, but also for estimating their impact upon health, thus contributing to the identification of vulnerable or high exposure risk groups. Biometrology is a tool for risk assessment and management that enables the priorities for public health actions to be determined. The levels measured may lead to the proposal of reference values, indispensable for the interpretation of exposure biomarker results measured in a context of contamination presumed to be of an environmental (acute, sub-acute or chronic exposure) or occupational origin. Biomonitoring programmes for the populations have been gradually put in place in several countries since the 1970′s, in particular in the USA (National Health and Nutrition Examination Survey, NHANES) (CDC, 2014), Canada (Canadian Health Measures Survey, CHMS) (Health Canada, 2013). Germany (German Environmental Surveys, GerES) (Becker et al., 2007; Schulz et al., 2007a), Czech Republic (Czech Human Biological Monitoring project) (Batáriová et al., 2006; Cerná et al., 2007, 2012), Belgium (Flemish Human Biomonitoring) (Schoeters et al., 2012; Vrijens et al., 2014, Baeyens et al., 2014), Italy (PROgramme for Biomonitoring of the Exposure, PROBE) (Bocca et al., 2010), Spain (BIOMAMBIENTS.ES) (Pérez-Gómez et al., 2013), Australia (Victorian Health Monitor) (Kelsall et al., 2013) and South Korea (Korea National Survey for Pollutants in the Human Body, KorSep/KNHANES) (Kim and Lee, 2011; Lee et al., 2012). In France the National Nutrition and Health Survey (ENNS) 2006–2007 enabled an initial estimation of the exposure of the general French population to many pollutants including metals, pesticides and non- dioxin-like PCBs (Fréry et al., 2010, 2012). These human biomonitoring data enable the pollutant levels in a given population to be determined for a given period. The particular ethnic features, the differences in lifestyle or eating habits, the specifics in terms of occupational activities and the levels of environmental pollution may all explain the variations observed in the various surveys. Furthermore, the results of prospective follow-ups also show the exposure variations in these populations over the course of time. Hence it is useful to have data available not only from different countries, but also from different regions within the same country.

Regional inequalities from a health standpoint are seen in France. Northern France (Nord – Pas-de-Calais region) is densely populated (more than 500 inhabitants/km^2) and is characterised by an abnormally high premature death rate and abnormally high cancer and cardiovascular disease death rates (ARS, 2011). The lifestyles and eating habits may contribute to these disparities. Furthermore, this region, a former mining area, has a marked industrial past, especially as regards the metallurgical industry, which explains its specificity in terms of environmental pollution (INSEE, 2014). It thus appeared useful to assess, with the aid of biomonitoring, the level of exposure to various environmental pollutants of the general population in this region.

2. Materials and methods

2.1. Study design and study population

A cross-sectional descriptive survey of blood and urinary metal levels in the general population was conducted in Northern France between May 2008 and September 2010, named IMEPOGE. The promoter of the study was the Lille University Hospital. The North-West II Committee of Protection of Persons gave a favourable opinion on the implementation of this protocol dated 17 April 2008 (No ID RCB 2007-A01358-45) as did the Directorate-General for Health (No DGS2008-0026).

Two thousand males and females of the general population aged between 20 and 59 years were recruited at the time of their health check-ups at one of the 7 Health Examination Centres in Northern France located in the cities of Lille, Douai, Roubaix, Tourcoing, Cambrai, Valenciennes and Dunkirk. In order to obtain a sample as close as possible to the characteristics of the general adult population of the region, the quota method was used. The most recent regional statistics at the time of the preparation of the study (1999 census conducted by the National Institute of Economic Statistics and Studies, INSEE) were used to produce a precise model of the distribution of the population to be included in each recruitment centre according to sex, age (in 10-year groups), tobacco smoking, socio-professional categories (farmers, self-employed workers/shop-keepers/small-business managers, executives/senior intellectual workers, middle executives, employees, blue collar workers, retired people, other unemployed people).

In order to limit the selection biases inherent in the use of the non-probability quota sampling method, precautions were taken: the recruitment took place within each of the region's seven Health Examination Centres, so as to recruit participants from the whole of the area covered by the study; furthermore, the size of the sample to be recruited in each of the centres was proportional to the size of the population covered by these centres; finally, in each Health Examination Centre, the investigators systematically proposed the study to anyone attending, without any discrimination whatsoever until the required quotas were obtained.

2.2. Individual data collection

After having been fully informed by a medical practitioner and signing informed consent documents, the people meeting the recruitment criteria were invited to complete a standardized self-questionnaire, comprising personal data (eating habits, medicine or food supplements consumed, tobacco smoking, medical history, leisure activities), occupational data (current job and business sector, occupational exposure, in particular to metals) and environmental data (place of residence, type of residence and renovation work, DIY activities). The biometric data (weight, height, blood pressure) was filled in by the physician or the nurse, and a dental examination was performed by a dentist in order to identify any metal amalgams and prostheses.

A venous blood sample (6 ml of blood in a special tube for metal trace elements determination) and a urine sample (30 ml in a polypropylene bottle) were collected in the morning during the health check-up, and immediately stored at +4 °C then sent by special delivery to the Biological Resources Centre of the Lille University Hospital. Aliquots of the urine samples were frozen at −20 °C, whereas the blood samples were immediately sent to the laboratory for analysis.

For the blood samples, 2 different tubes specially designed for metal trace elements determination were used, as they cor-