Short communication

The French human biomonitoring program: First lessons from the perinatal component and future needs

Clémentine Dereumeaux a,∗, Clémence Fillol a, Marie-Aline Charles b, Sébastien Denys a

a Direction of Environmental Health, Santé Publique France, Saint Maurice Cedex, France
b French National Institute for Health and Medical Research (Inserm), The “Elfe” INED-INSERM-EFS team, France

A R T I C L E   I N F O

Article history:
Received 29 June 2016
Received in revised form 21 October 2016
Accepted 11 November 2016

Keywords:
Human biomonitoring
France
Environmental exposure
Biomarkers
Endocrine disruptor
Metals

A B S T R A C T

This paper presents a progress report of the French human biomonitoring (HBM) program established in 2010. This program has been designed to provide a national representative estimation of the French population’s exposure to various environmental chemicals and to study the determinants of exposure. This program currently consists in two surveys: a perinatal component related to a selection of 4145 pregnant women who have been enrolled in the Elfe cohort (the French Longitudinal Study since Childhood) in 2011, and a general population survey related to adults aged 18–74 years and children as from 6 years (Esteban). The aim of this manuscript is to present highlights of the French human biomonitoring program with particular focus on the prioritization of biomarkers to be analyzed in the program and the selection of biomarkers applied to both program components.

The Delphi method was used to establish a consensual list of prioritized biomarkers in 2011. First results of the perinatal component of the French HBM program have shown that the biomarkers prioritized were relevant, as almost all pregnant women were exposed to them. However, for some biomarkers, levels’ decreases have been observed which may partly be explained by measures taken to prohibit some of these chemicals (e.g. atrazine) and by industrial processes evolutions leading to the substitution of others (e.g. bisphenol A, di-2-ethylhexyl phthalate/DEHP, dialkyl phosphates). Therefore, the list of biomarkers to be monitored in the French HBM program has been implemented to include some substitutes of biomarkers prioritized in the first instance (e.g. bisphenol S, F). Finally, this method combines rigor and flexibility and helped us to build a prioritized list that will be shared and supported by many if not all actors.

© 2016 Elsevier GmbH. All rights reserved.

1. Introduction

Human biomonitoring (HBM) is the analytical measurement of biomarkers (e.g. environmental chemicals or their metabolites) in easily accessible human biological fluids and tissues (e.g. urine, blood, hair) (Angerer et al., 2006). As HBM represents an integral measure of exposure from all relevant sources and routes of uptake, it permits a new approach to exposure assessment even when the quantity and quality of external exposures are unknown or ambiguous (Wittassek et al., 2011). This is particularly true for chemicals present in food or used in a variety of everyday life products, including food packaging, and responsible for a widespread human exposure.

Until recently, the HBM studies conducted in France have focused on specific populations exposed to specific pollutants such as lead (Etchevers et al., 2015), cadmium and arsenic (Fillol et al., 2010), mercury (Cardoso et al., 2010), and dioxins (Zeghnoun et al., 2007). However, since the early 2000s, national multipollutant HBM studies have been implemented in France by Santé publique France (previously known as Institut de veille sanitaire, InVS) at instigation from various French policies. The French national nutrition survey (ENNS) was the first French biomonitoring study which has provided a national representative description of biomarkers levels of several environmental chemicals including metals, pesticides and no dioxin-like PCBs during the period 2006–2007 (Falq et al., 2011; Frey et al., 2012). The ENNS survey can be considered as the bridgehead of the current French human biomonitoring program established in 2010. This program consists now of two distinct cross-sectional national biomonitoring surveys:

http://dx.doi.org/10.1016/j.ijheh.2016.11.005
1438-4639/© 2016 Elsevier GmbH. All rights reserved.

Please cite this article in press as: Dereumeaux, C., et al., The French human biomonitoring program: First lessons from the perinatal component and future needs. Int. J. Hyg. Environ. Health (2016), http://dx.doi.org/10.1016/j.ijheh.2016.11.005
– a perinatal component based on a selection of pregnant women enrolled in the French Longitudinal Study since Childhood (Elfe), in 2011;

The objective of this paper is to make a progress report a few years after the launch of the French national biomonitoring program, with particular focus on the prioritization of biomarkers to be analyzed in the program and the selection of biomarkers applied to both program components.

2. The French HBM program: definition and harmonization

2.1. Context and aims

The French HBM program is scheduled in the French Grenelle Law for environment (n° 2009-967 of August 3, 2009), and in the 2nd and 3rd French National Environmental Health Plans (2009–2013, 2015–2019). The outlines of this program were defined by a steering committee including Santé publique France, the French Health and Environment ministries and other French Public Health Agencies. This program has been 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 objectives of this program are: i) describe the impregnation, and analyze its determinants in the general population or particular populations for providing information to the public and decision makers and establish the reference values, ii) monitor exposures (spatial and temporal trends) by repetition of investigations, iii) guide, monitor and evaluate the effectiveness of reduction strategies for human exposure, iv) alert the authorities in case of emerging phenomena. The French HBM program also expects to compare the biomarkers levels with those observed in previous surveys, including in previous European biomonitoring surveys.

In this context, elaborating a harmonized design to apply in the two studies of the French HBM program and applicable to further French biomonitoring surveys was essential. At the European level, efforts were also made to harmonize approaches to HBM. Therefore Santé publique France endeavored to translate into the national level the European recommendations made in the framework of projects such as COPHES (Consortium to Perform Human biomonitoring on a European Scale).

2.2. Selection of biomarkers

Concentrated efforts were made to choose and prioritize biomarkers studied in the perinatal component and Esteban. Therefore a prioritization method was developed based on consensual selection criteria that would be applied in a formalized approach in order to reach a final list of biomarkers to be monitored in the French population. The entire process has been previously well described (Fillol et al., 2014).

The first phase consisted in building the most exhaustive list of exposure biomarkers of interest. This list was defined by a workshop including Santé publique France (InVS), Ministry of Health, Ministry of Environment, and other public health agencies. Finally, 50 groups of biomarkers were selected owing to the biomonitoring feasibility (from international and French experience), the exposure relevance (use and key information on the toxicity of substances), the existing regulations for the compounds (in air or in water), and the priorities in terms of health effects and exposure factors.

The second phase of the process consisted in prioritizing the classified list of 50 groups of biomarkers. The Delphi consensus method was used for prioritization and was developed in three steps: (i) the definition of relevant criteria for selecting biomarkers; (ii) the prioritization of the biomarker list on the basis of these criteria and (iii) the validation of the list by the stakeholders (Fink et al., 1984). A group of 21 experts (11 French-speaking experts and 10 international experts) were involved in this process. Each expert ignored who else was participating in this prioritization. In the first step, eight criteria were defined and proposed to classify the biomarkers: contribution in terms of new knowledge in France, feasibility of the prevention, logistic and analytic feasibility, feasibility of results’ interpretation, biomarker characteristics (i.e. meaning of the marker, sensitivity, specificity, intra-individual variability of the marker, etc.), social perception, exposure characteristics (i.e. origin of the contamination, dispersion of the contamination, the potential human exposure and the group of population concerned) and hazard identification. The experts were asked to rate these criteria from 0 if the criterion is not relevant to 10 if it is very relevant, and to justify their choices. According to the Delphi method, each expert was able to confirm or modify his choice once the answers of all experts had been compiled. Hazard identification was the highest-rated criterion whereas social perception was the lowest-rated. In the second step, each expert was asked to rate the 50 groups of biomarkers according to the 8 criteria. The score obtained for each biomarkers group was used to rank them in order of priority. The final prioritized list of biomarkers was submitted to the experts for approval (step 3). Within families of biomarkers, “priority A” (first half of the list) and “priority B” (second half of the list) were identified. This combination was a demand from stakeholders to improve the clarity of the list. Finally, the final prioritized list obtained contained both historic pollutants such as dioxins or lead and emerging pollutants. The prioritized list of biomarkers is detailed in Supplemental Material.

3. The perinatal component of the French HBM program: first feedback

3.1. Context and aims

The perinatal component of the French HBM program was based on a random selection of mothers who have been enrolled in the Elfe cohort. The Elfe cohort is a longitudinal study that has enrolled 18,000 children in 2011 for a projected 20 years follow up in order to characterize the relationship between the environment and the development, health and socialization of the children. The environment of the child is characterized with a multidisciplinary approach assessing socioeconomic, geographic, familial, behavior-related, physical, chemical and microbiological exposures.

The primary aim of the perinatal component of the French HBM program was to describe concentrations of prioritized biomarkers among pregnant women having given birth in continental France in 2011. Additional objectives included the following: (i) to compare the biomarkers levels with those observed in previous surveys conducted in France and abroad (e.g. in other European HBM programs) and with available HBM reference values; (ii) to identify and quantify, when possible, the determinants of exposure.

Exposure biomarkers were measured in biological samples of the pregnant woman collected at delivery, just after her admission to the maternity unit (urine), in the delivery room (blood and cord blood) or within the first few days following birth (hair).
3.2. Materials and methods

The design of the cohort has been previously described (Charles et al., 2011; Vandonterren et al., 2009). The questionnaires, sampling protocols, transportation conditions, and analytical methods have been defined and validated by a pilot survey conducted in 2007 (Vandonterren and Oleko, 2011). This pilot has enrolled about 300 families in two French regions (Rhône-Alpes and Seine-Saint-Denis). Some emerging pollutants were monitored in this pilot study: bisphenol A (BPA), phthalates, brominated flame retardants (BFRs), perfluorinated compounds (PFCs), some pesticides and their metabolites (atrazine, glyphosate, carbamates, pyrethroids), and organotin compounds (Vandonterren et al., 2013).

The study population of the perinatal component of the French HBM program was a random selection of mothers enrolled in the Elfe cohort. These women had to be adult (>18 years), to have given birth to a single or two living babies, after 33 weeks or more of gestation, in one of the 211 maternity hospitals participating in the biological data collection located in continental France. These maternity units had been chosen in order to guarantee the regional coverage expected to have a representative sample of the pregnant women having given birth in continental France in 2011. The pregnant women 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. These intake periods were defined to represent the seasonal variability of exposure to some chemical (e.g. pesticides). For each biomarker analyzer a subsample of participants was selected among pregnant women who had at least one biological sample available. The number of pregnant women per maternity stratum was chosen in such a way as to preserve the original distribution according to the institution status (private or public), authorization type, and geographical area of the maternity unit. An informed consent to participating in the biological samples collection of the Elfe cohort was required.

Biological sample collection protocol as well as aliquoting, transportation and storage conditions were defined in the framework of the Elfe cohort and validated in the pilot study. More precisely, spot urine samples were collected at arrival at the maternity in a 150 mL polypropylene container; blood was collected by venous catheter and stored in one or two dry 10 mL tubes; cord blood was sampled in 6 mL EDTA tubes. All samples were stored at +4 °C in the hospital and transferred in refrigerated trucks twice a day to biobanks where they were processed. Samples of urine and serum were then aliquoted in 10 mL or 2 mL polypropylene cryotubes. Total cord blood was aliquoted from EDTA tubes to 0.5 mL straws. In biobanks, urine and maternal blood samples were stored at −80 °C and cord blood straws were stored at −196 °C. Time between sampling and freezing did not exceed 36 h for all samples. A strand of hair was cut in the occipital area of the pregnant woman’s head. It was then stapled to a paper card, indicating the orientation (tip/root) of the strand, and stored at ambient temperature. Biological samples used for the study were sent to the laboratories that carried out the biomarkers analysis (Idhesa, Laberca, Chemtox and the Toxicology Center of the National Institute of Public Health of Québec). Transportation was realized in dry-ice (≤−60 °C) and did not exceed 24 h for laboratories located in France and 96 h for the laboratory located in Canada. In laboratories, samples were stored at −20 °C and protected from light (except hair).

The biomarkers analyzed in the perinatal component of the French HBM program were those prioritized by the Delphi consensus method. However, all of the biomarkers listed could not be measured in the study. Indeed, biological sample protocol was defined before the establishment of the prioritization, and was inappropriate for ensuring the preservation of some chemicals such as benzene, volatile organic compounds (VOCs) and polycyclic aromatic compound (PACs). Moreover, because of feasibility (availability of biological samples) and budgetary constraints, some of the biomarkers prioritized B (e.g. glycol ether, paraben, mycotoxins) have not been included in the survey. Additionally, as the pilot survey has shown that organotin compounds were nearly undetectable in all urine samples of pregnant mothers (Vandonterren et al., 2013), these biomarkers have not been retained in the national study. Biomarkers finally monitored in the perinatal

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Main characteristics of pregnant women selected in the perinatal component of the French HBM program in 2011 and comparison with the target population.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td>Sample size</td>
</tr>
<tr>
<td>Age – Classes (%)</td>
<td>18 to 21 years</td>
</tr>
<tr>
<td>101</td>
<td>202</td>
</tr>
<tr>
<td>Gestational age (%)</td>
<td>≤ 37 weeks</td>
</tr>
<tr>
<td>12.3</td>
<td>69.2</td>
</tr>
<tr>
<td>Education level (%)</td>
<td>None/primary education</td>
</tr>
<tr>
<td>Birthplace (%)</td>
<td>France</td>
</tr>
<tr>
<td>Marital status (%)</td>
<td>Married</td>
</tr>
<tr>
<td>Nationality (%)</td>
<td>French</td>
</tr>
<tr>
<td>BMI before pregnancy (%)</td>
<td>&lt;18.5 kg/m²</td>
</tr>
<tr>
<td>Gestational diabetes (%)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

NA: not available.


* Calibration covariate.
component of the French HBM program are listed in Supplemental Material.

Retrospective data about life style during pregnancy (e.g. smoking and alcohol), potential sources of chemical exposure (e.g. use of pesticides during pregnancy), occupational and housing characteristics, medical history, sociodemographic and anthropometric characteristics were collected via questionnaires during the maternity stay (a face-to-face interview, a food frequency self-administered questionnaire) and a telephone interview 2 months later. The answers were used to create indicators of exposure to environmental chemicals during pregnancy (e.g. sums of items constituting common sources of exposure, information about the possible presence of crops or factories in the municipality of residence of the pregnant woman, etc.).

3.3. First highlights

Among the 18,000 mothers enrolled in the Elfe cohort, 4145 pregnant women have been included in the perinatal component of the French HBM program. Table 1 shows the main characteristics of the study population. The proportion of primipara mothers was 43.0%, and mean age was 30.3 years (min: 18 years, max: 47 years). In the present study 83% were born in France, 30% were living in the regions Ile-de-France, Picardie and Centre, 35% were living in Northern regions of France and other 35% in southern regions of France. Almost 30% of the study population did not achieved high school and higher education and 18.1% was unemployed. Approximately a third of all pregnant women were overweight (body mass index, BMI 25–30 kg/m²) or obese (BMI >30 kg/m²) before the present pregnancy. Gestational age at delivery was below 37 weeks for almost 9% of the mothers. About 8% of the pregnant women declared having gestational diabetes during their pregnancy. Considering these characteristics, the subsample of pregnant women included in our study was reflective of the main characteristics of the target population (i.e. the whole pregnant women population having given birth in France in 2011). However, in some regions of France (Picardie, Haute-Normandie, Centre, Ile-de-France) no or very few maternity units participated in the serum collection for the Elfe cohort. This impaired the regional coverage expected to have a representative sample of the pregnant women having given birth in continental France in 2011. Moreover, hemolysis has limited the availability of some of the serum samples for the measurements of persistent organic pollutants. Therefore, we considered that the sample of pregnant women selected for serum analyses was not representative of the pregnant women having given birth in continental France in 2011.

In the perinatal component of the French HBM program, BPA, phthalates, pyrethroids, dioxins, furans, PBs, PCBs, BFRs (except
Table 3
Comparison of BPA, MEHP, Atrazine mercapturate, DMP, DEP and 3-PBA levels in studies conducted in France and abroad (in µg/L).

<table>
<thead>
<tr>
<th>Country</th>
<th>Study</th>
<th>Year</th>
<th>BPA</th>
<th>MEHP</th>
<th>Atrazine mercapturate</th>
<th>DMP</th>
<th>DEP</th>
<th>3-PBA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>n</td>
<td>% &gt; LOQ (LOQ)</td>
<td>GM</td>
<td>n</td>
<td>% &gt; LOQ (LOQ)</td>
<td>GM</td>
</tr>
<tr>
<td>France</td>
<td>Our study</td>
<td>2011</td>
<td>1764</td>
<td>74 (0.3)</td>
<td>0.7</td>
<td>989</td>
<td>71 (0.7)</td>
<td>1.6</td>
</tr>
<tr>
<td>France</td>
<td>Elle pilot</td>
<td>2007</td>
<td>254</td>
<td>97 (0.3)</td>
<td>2.6</td>
<td>279</td>
<td>91 (2.0)</td>
<td>12.9</td>
</tr>
<tr>
<td>France</td>
<td>Pelage, Chevrier et al. (2011)</td>
<td>2002–06</td>
<td>191</td>
<td>99 (0.4)</td>
<td>2.7</td>
<td>287</td>
<td>92 (1.2)</td>
<td>7.1</td>
</tr>
<tr>
<td>France</td>
<td>Eden/Pelage, Philippat et al. (2012), Philippat et al. (2014)</td>
<td>2002–06</td>
<td>191</td>
<td>99 (0.4)</td>
<td>2.7</td>
<td>287</td>
<td>92 (1.2)</td>
<td>7.1</td>
</tr>
<tr>
<td>Norway</td>
<td>Moba, Ye et al. (2009)</td>
<td>1999–04</td>
<td>110</td>
<td>110 (0.3)</td>
<td>2.8</td>
<td>110</td>
<td>110 (0.5–2)</td>
<td>22.3</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Generation R, Ye et al. (2008)</td>
<td>2004–06</td>
<td>100</td>
<td>100</td>
<td>100 (0.3)</td>
<td>6.9</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Spain</td>
<td>Inma, Casas et al. (2015), Valvi et al. (2015)</td>
<td>2004–06</td>
<td>479</td>
<td>99 (0.1)</td>
<td>1.8</td>
<td>390</td>
<td>99 (1.0)</td>
<td>9.6</td>
</tr>
<tr>
<td>United-States</td>
<td>Chaminos, Castorina et al. (2010), Harley et al. (2013)</td>
<td>1999–2000</td>
<td>402</td>
<td>82 (0.4)</td>
<td>1.1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>United-States</td>
<td>Nhanes, Woodruff et al. (2011)</td>
<td>1999–2004</td>
<td>86</td>
<td>96 (0.4)</td>
<td>2.5</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>United-States</td>
<td>Tides, Serrano et al. (2014)</td>
<td>2010–2012</td>
<td>8</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Canada</td>
<td>Mire, Arbeckle et al. (2014), Shapiro et al. (2016)</td>
<td>2008–2011</td>
<td>1936</td>
<td>88 (0.2)</td>
<td>0.8</td>
<td>1788</td>
<td>97 (0.2)</td>
<td>2.2</td>
</tr>
</tbody>
</table>

GM: geometric mean.
* NC: geometric mean not calculated because of large amount of left-censored biomarker levels (% > detection <60%).
* N/A: biomarker not included in the study. 'Median.
* ND: data not published.
* Result published in nmol/L and converted in µg/L in this table.
PBB-153 and HBCD), PFCs and metals (except uranium) were quantified in almost all women (Table 2). These findings have shown that pregnant women were widely exposed to the biomarkers prioritized in the framework of the French HBM program, even if some of them are henceforth banned or restricted in France. It also confirmed the relevance of the list of biomarkers prioritized by experts.

Levels of some chemicals, especially BPA, phthalates (Mono-2-ethylhexyl phthalate/MEHP) and pesticides (atrazine, Di-methylphosphate/DMP and Di-ethyl-phosphate/DEP), observed in the perinatal component were slightly lower than those observed in previous studies in France and abroad (Table 3). These decreases may partly be explained by measures taken to prohibit some of these chemicals (atrazine) and by industrial processes evolutions leading to the substitution of others (BPA, DEHP, dialkyphosphates). This has underlined the necessity to study the substitutes of biomarkers prioritized in the first instance (e.g. bisphenol S, bisphenol F, DINCH) in further biomonitoring studies conducted in France.

The results of the perinatal component of the French HBM program have also highlighted the existence of an overexposure of the French pregnant women to pyrethroids (e.g. 3-phenoxybenzoic/3-PBA) in comparison with the U.S. pregnant women (Table 3). This finding was consistent with the first observation made in the ENNS study for the general population in 2007, and confirmed the need to monitor very closely and carefully the situation regarding exposure of the French population to pesticides. However, we must remain cautious in interpretation because these substances were analyzed for the first time in France on a representative sample of this specific population of women who gave birth. Moreover, the existence of a potential misclassification of exposure could not be excluded because of the circadian variability of short half-life biomarkers concentrations.

4. Esteban: further needs

As part of the French human biomonitoring program, Esteban is a cross-sectional study representative of the population aged from 6 to 74 years old, and living in continental France during the period 2014–2016. About 3000 adults (18–74 years old) and 1300 children (6–17 years-old) have been included in the study. The participants have been randomly selected from the whole territory of France and recruited by phone. Informed consent was obtained from participants. Data concerning health, nutrition, chemicals exposure and socio-demographic characteristics have been collected through two interview guided questionnaires, self-administered questionnaires, a 24 h dietary recalls, and a health examination including fasting biological samples collection (blood, urine and hair). Samples were collected at the participants’ home by a nurse or in a Health Insurance examination center. More precisely, the first morning urines were collected by the participant at his home (150 ml for children and 200 ml for adults) in a polypropylene container. The participants bring the urines to the health examination center or left them to the nurse. Blood was collected by venous catheter: 26 ml for children aged 6 to 11 years old; 36 ml for children aged 12 to 17 years old and 88 ml for adults. Samples of urine and serum were then aliquoted in 10 ml 5 ml, 3 ml or 1.2 ml polypropylene cryotubes. A strand of hair was cut in the occipital area of the children and adult’s head. It was then stapled to a paper card, indicating the orientation (tip/root) of the strand, and stored at ambient temperature. Biological samples were sent to a biobank, for long term conservation at −80 °C.

4.1. Biomarkers measurements will start during the second half-year of 2016

As far as possible the feedbacks of the perinatal component of the French HBM program have been used to improve in a small scale the methodological aspects of the Esteban study, including the list of biomarkers prioritized. Moreover, in the Esteban study, the collection of first morning study and the availability of data about recent food consumptions may prevent the limitations observed in the perinatal component of the French HBM program. Unfortunately, the biological sample protocol was also inappropriate for ensuring the preservation of most of the volatile organic compounds (VOCs). As VOCs or their metabolites are rarely detected in studies conducted abroad, they will not be measured in Esteban in agreement with the scientific council of the study. However it was decided to measure in the urine in addition to benzene, toluene, styrene, xylene and ethylbenzene.

Moreover, the prioritized list of biomarkers has been updated and as the results of the perinatal component of the French HBM program underlined the necessity to study exposure to alternatives of bisphenol A, it has been decided to include bisphenol S and F to the list of biomarkers to be analyzed in the Esteban survey.

All other biomarkers of prioritized list should be analyzed. The list of biomarkers analyzed in Esteban is listed in Supplemental Material.

5. Conclusion and perspectives

The French HBM program is implemented by Santé publique France and currently consists in two distinct surveys: a perinatal component based on a selection of pregnant women enrolled in the Elfe cohort and a general population survey representative of the population aged from 6 to 74 years old (Esteban). In this context, elaborating a harmonized design to apply in these two studies was essential. Concentrated efforts have been made to choose and prioritize the biomarkers to monitor in the perinatal component and the Esteban survey.

This prioritization process was long and sometimes arduous but useful in terms of traceability of the final selection of biomarkers included in the French human biomonitoring program.

First results of the perinatal component of the French HBM program have shown that the biomarkers prioritized were relevant, as almost all pregnant women were exposed to them. The selection of biomarkers also maintains the flexibility required to ensure small scale changes, considering feedbacks from the first component of the French HBM program. Finally, this method combines rigor and flexibility and helped us to build a prioritized list that will be shared and supported by many if not all actors.

Regarding perspectives, the results of analysis for biomarkers produced in the perinatal biomonitoring component of the national program are being made available to research’s teams who will study relationships with health in the Elfe cohort. In addition, all results produced as part of the national biomonitoring program will help inform the authorities with data obtained on exposure and exposure monitoring of the French population to all environmental substances dosed.

Acknowledgments

- The French human biomonitoring program is funded by the French ministries of Health and Environment.
- Elfe is a study conducted conjointly by National Institute of Demographic Studies (Ined), French National Institute for Health and Medical Research (Inserm), French blood establishment (EFS), French Institute for Public Health Surveillance (InVS). French
National Institute for Statistics and Economic Studies (Insee), General Directorate for Health (DGS, Ministry of Health), General Directorate for Risk Prevention (DGPR, Ministry of Environment), Directorate for Research, Studies, Evaluation and Statistics (Drees) and French National Family Allowance Fund (Café). It benefits from additional fundings from the Ministry of Research, Committee on SHS data (CCDHS) and Ministry of Culture and Communication (Dep). As part of the RECONAL platform, Elefe benefits from a National research agency funding (ANR-11-EQPX-0038).

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijheh.2016.11.005.

References


Fillol, C., Garnier, R., Mullot, JU., Boudet, C., Monas, I., Salmi, L.R., et al., 2014. Prioritization of the biomarkers to be analyzed in the french biomonitoring program. Biomonitoring 1, 95–104.


