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Early snapshot on exposure to environmental chemicals among Korean adults—results of the first Korean National Environmental Health Survey (2009–2011)

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ABSTRACT

Background: Chemical exposure may cause serious adverse health effects. Under the Environmental Health Act in Korea, the first national survey, Korean National Environmental Health Survey (KoNHES), was conducted, and dozens of major environmental chemicals were measured among Korean adults between 2009 and 2011.
Objectives: To understand the levels of exposure to environmental chemicals among general Korean adults population, and to identify factors that may influence the levels of exposure.
Methods: The blood and urine samples were collected from Korean adults with 19 years of age and older (n = 6311), and were analyzed for a number of environmental chemicals including metals, bisphenol A (BPA), and metabolites of polycyclic aromatic hydrocarbons (PAHs), phthalates, a pyrethroid insecticide (3-PBA) and several volatile organic carbons (VOCs). Demographic and other behavioral factors were asked through questionnaire.
Results: Among general Korean adults, mercury, arsenic, cadmium, and metabolite of DBP (MnBP) were higher than those reported in other nationwide surveys of Canada, Germany, and USA. Most target chemicals except for MEOHP and 3-PBA showed significant differences on the exposure levels by sex
Conclusion: This is the first nationwide reconnaissance on exposure to environmental chemicals among general Korean population. Chemicals with high occurrence level will be further investigated to identify exposure sources and possible health outcomes, and eventually to develop measures to mitigate exposure.

1. Introduction

Human biomonitoring (HBM) is a measurement of the chemicals and their metabolites in human biological samples, such as tissues and fluids. HBM has been successfully employed to determine the exposure levels of environmental chemicals among humans and to identify vulnerable or high risk groups (Angerer et al., 2007). In addition, the results of HBM can be used to design subsequent efforts to identify important exposure sources. For these reasons, a number of countries have initiated HBM programs for general population at different scale (Becker et al., 2002, 2003; Casteleyn et al., 2007; CDC, 2009; Haines and Murray, 2012). The information gleaned from HBM programs has been utilized to develop environmental health policy measures (Christensen, 1995; Hays et al., 2007; Kolossa-Gehring, 2012; National Research Council, 2006).

In Korea, HBM programs for general population have been initiated at as early as in 2005, i.e., Korea National Survey for Environmental Pollutants in the Human Body (KorSEP), as a preliminary effort to define the scope and procedures of HBM program of the nation. In this program, mercury, lead and cadmium were chosen as target chemicals and analyzed among general Korean adults population (n = 2000). This program has been followed by two additional rounds in 2007 (n = 2324) and 2008 (n = 5129) (National Institute of Environmental Research, 2005, 2007, 2008a). Through these efforts, occurrences of several major environmental chemicals were

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determined, and utility of HBM in developing environmental health management policy was demonstrated. For example, in 2006, the Ministry of Environment of Korea devised comprehensive measure for the management of mercury, and strengthened the regulation for the use of mercury. However, this program was conducted as a part of Korean National Health and Nutrition Examination Survey (KNHANES) of Ministry of Health and Welfare of Korea, and was not intended for exposure assessment. The target populations were not representative of the age and sex distribution of Korean population, and the sampling seasons were often skewed.

Environmental Health Act (enacted in 2008) of Korea requires Korean government to conduct national HBM program in every 3 years to describe the exposure profile of major environmental chemicals and to identify major factors that are associated with the exposure. For this purpose, the Korean National Environmental Health Survey (KoNEHS) was designed as a part of regulatory program, and has been implemented in 2009. Approximately 6000 Korean adults were recruited, and measured for major metals, metabolites of PAHs, phthalates, environmental phenols, pyrethroid pesticides, VOCs, and nicotine. The results of the KoNEHS could be applied to identify exposure sources and pathways, and to support developing and implementing environmental health management options.

The purpose of this report is to present the first snapshots of the biomonitoring results from the first KoNHES.

2. Materials and methods

2.1. Study design

The first round of KoNHES was conducted from 2009 to 2011 by the National Institute of Environmental Research, Korea. This survey was designed to determine the exposure level of environmental chemicals among Korean adults population (aged 19 years or older). Institutionalized people were not included. In order to generate exposure profiles representing the adult population of nation, the KoNHES required a minimum population size of at least 6000 subjects based on the results of the preliminary biomonitoring study. To identify the subjects, a two-stage, proportionally stratified sampling design was developed based on sex, age and geographical characteristics as of 2005. The first stratification stage was based on geographical area, i.e., 16 administrative districts and 1 coastal stratum. And the second stage was consisted of 59 strata defined by socioeconomic categories, e.g., residential types for urban areas; agricultural/non-agricultural status for rural areas, and 1 stratum consisting of areas in which air pollution monitoring stations were installed. Among a total of 264,183 primary sampling units with about 60 households or 200 persons per sampling unit, 350 primary sampling units were chosen. Among 350 primary sampling units, the 300 sampling units were randomly allocated based on proportional to the square root of the population size in each stratum, and the remaining 50 sampling units were allocated to the area where air pollution monitoring station was installed. These 350 primary sampling units were surveyed and sampled. At least 20 households or 24 persons were recruited for each sampling unit.

For recruiting subjects, a survey team member visited households 3 ~ 7 days before the actual survey, and communicated with potential subjects and explained the purpose of the survey. If eligible household member agrees to participate, then survey team member proceeded with brief questionnaire which included basic demographic characteristics, and informed the time and location, e.g., regional community centers or public health centers, of actual survey, and other requirements. To increase the response rate, the survey team called the subjects a day before the actual survey. An informed consent was obtained from the participant before an interview. Through a face-to-face interview by trained personnel, questionnaire was completed. The questionnaire included questions on 7 categories including demographic and socioeconomic information, family history, indoor and outdoor environments, occupational history, dietary habits, and life-style related with environmental chemical exposure. Then, the blood and urine samples were collected by a nurse or medical technologist under the supervision of a doctor.

To ensure confidentiality and security of the subjects and data, the questionnaire and biological sample were managed by a bar code system. Questionnaire data and analytical data were put into separate databases, and personal identification details of the subjects were encrypted. This survey was approved by the Research Ethics Committee of the National Institute of Environmental Research.

The target chemicals measured in the first KoNEHS were selected based on (1) known adverse health effects; (2) possible association with environmental and behavioral factors; (3) availability of analytical methods; and (4) emerging environmental health issues.

A total of 16 chemicals were selected, and these included five metals, i.e., lead (Pb), total mercury (Hg), and manganese (Mn) in blood and total mercury (Hg), cadmium (Cd) and inorganic-related arsenic (As) in urine, two PAH metabolites, i.e., 1-hydroxypyrene: 1-OHP, 2-hydroxynaphthalene: 2-naphthol, three phthalate metabolites, i.e., mono-(2-ethyl-5-hydroxyhexyl) phthalate: MEHHP, Mono-(2-ethyl-5-oxohexyl) phthalate: MEOHP, Mono-*n*-butyl phthalate: MnBP), bisphenol A, a pyrethroid insecticide metabolite, i.e., 3-phenoxybenzoic acid: 3-PBA, and five VOCs metabolites, i.e., muconic acid, hippuric acid, mandelic acid, phenylglycoxylic acid and methylhippuric acid, in urine.

Sample collection and analysis were carried out in accordance with standard protocols previously established for previous national HBM program (Lee et al., 2012; Sul et al., 2012). About 5 ~ 6 mL whole blood samples were collected for analysis of Hg, Mn and Pb. Spot urine specimens (>80 mL) were collected and analyzed for inorganic As (arsenic acid, arsenous acid, monomethyl arsonic acid and dimethyl arsinic acid), Cd, Hg, and metabolites of organic chemicals. To ensure that the samples were not contaminated or compromised, field blanks were employed throughout the survey and analysis, and an internet-based tracking system, hand-to-hand and a cold chain system were used for sample delivery. The samples were delivered in a cooler (0–4 °C) equipped with temperature logger and were stored at −20 °C within 48 h of sampling.

2.2. Instrumental analysis and quality Assurance/Quality control

Pb, Mn and Cd were measured by graphite furnace atomic absorption spectrometry with Zeeman background correction (Brodie and Routh, 1984). Inorganic arsenics, i.e., arsenic (V) acid or As (V), arsenous (III) acid or As (III), dimethyl arsinic acid or DMA, and monomethyl arsonic acid or MMA, were measured by hydride generation-atomic absorption spectrometry with a muffle furnace atomizer (Guo et al., 1997), and total mercury in blood and urine were measured by Direct Mercury Analyzer equipped with a cold vapor generator. The metabolites of PAHs, 3-PBA and cotinine were determined by GC–MS (Jongeneelen et al., 1985; Kim et al., 1999; Schettgen et al., 2002b; Man et al., 2006), phthalate metabolites, bisphenol A and muconic acid were determined by HPLC-tandem mass spectrometry, and metabolites of VOCs were HPLC–MS (Silva et al., 2003; Völkel et al., 2005; Melikian et al., 1999). Details of the instrumental analysis were described elsewhere (National Institute of Environmental Research 2006, 2008b)

For external quality control, all of the analytical laboratories participated in G-EQUAS and Special Health Quality Control programs. The Special Health Quality Control Programs is run by the

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