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Additional Deliverable AD4.8

Report on the occupational exposure in general population surveys: analysis of existing data and recommendations for future general population studies

WP 4 — T4.1

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Abstract

The current analysis is based on the six general population data sets from Belgium, France, Iceland, Israel, Lithuania, and Spain. The study focused on cadmium, chromium, PAH and bisphenols. Relevant occupations, in which exposure to these chemicals may occur were identified, the data was coded according to the International Standard Classification of Occupations 2008 (ISCO-08), and statistical analyses were performed to identify potential occupationally exposed group among these general population data sets.

The results suggested potential occupational exposure to bisphenol A among the occupational group consisting mostly of cashiers and ticket clerks and other store employees. This is in accordance with the known exposure of these workers to bisphenol A via thermal papers used in receipts. It needs to be noted, however, that the number of samples in the relevant ISCO-08 group was rather low and therefore, the results should be interpreted with caution.

The group “Cleaners and helpers in offices, hotels and other establishments” (ISCO-08 code 9112) showed elevated exposure to cadmium. The reason for the higher urinary levels of cadmium among this group remains unclear, but it is noted that this group may include also industrial cleaners exposed to cadmium in industrial settings.

For other chemicals, it was not possible to identify occupationally exposed groups from the available data set. The results of this study should be considered in future general population studies: especially the importance of high enough sample size and ISCO-08 encoding with at least 4 digits is highlighted. There are several possible confounding factors (e.g., smoking and diet) that may affect the results, especially when the size of certain occupational groups is small. Attention should also be paid to the timing of sample collection. This type of study design may work better with chemicals that have low background biomarker levels and low background variation in biomarker levels due to environmental exposure. Of the substances evaluated in this study, it is known that background levels of urinary cadmium, chromium, 1-hydroxypyrene and bisphenol A vary in the population due to non-occupational reasons, such as geographical location and, e.g., diet.

The results presented in this deliverable represent the preliminary analysis. Analyses are planned to be completed with additional data set from Portugal and the final results will be reported in a subsequent scientific article.

Key Words

Human biomonitoring (HBM), biological samples, exposure biomarkers, data analysis, exposure assessment, environmental exposure, occupational exposure, metals, BPA, BPA analogues.

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Acronyms

1-Pyr: 1-Hydroxypyrene, **BPA:** Bisphenol A, **BPF:** bisphenol F, **BPS:** Bisphenol S, **Cr(VI):** Hexavalent Chromium, **HBM:** Human Biomonitoring, **HBM4EU:** European Human Biomonitoring Initiative, **IARC:** International Agency for Research on Cancer, **ISCO:** International Standard Classification of Occupations, **LOD:** Limit of Detection, **LOQ:** Limit of Quantification, **OHBaP:** Hydroxybenzo[a]pyrene, **PAHs:** Polycyclic Aromatic Hydrocarbons, **PEH:** Personal Exposure and Health.

Glossary

Biomonitoring: Continuous or repeated measurement of potentially toxic substances or their metabolites in tissues, secreta, excreta, expired air, or any combination of these to evaluate occupational or environmental exposure and health risk by comparison with appropriate reference values based on knowledge of the probable relationship between ambient exposure and resultant health effects (IUPAC 2024).

Exposure: Process by which a substance becomes available for absorption by the target population, organism, organ, tissue or cell, by any route (IUPAC 2024).

Exposure biomarkers: Biomarker that relates exposure to a xenobiotic to the levels of the substance or its metabolite, or of the product of an interaction between the substance and some target molecule or cell that can be measured in a compartment within an organism (IUPAC 2024).

General population (biomonitoring) surveys: (Biomonitoring) surveys which are generally conducted using representative sample of the general population.

HBM4EU: The HBM4EU project was launched in 2016 with the aim of improving the collective understanding of human exposure to hazardous chemicals and developing HBM as an exposure assessment method. The project had €74m in funding and jointly implemented by 120 partners from 28 participating countries — 24 EU member states plus Norway, Switzerland, Iceland and Israel and the European Environment Agency. One of its aims was to ensure the sustainability of HBM in the EU beyond 2021. The project ended in June 2022 (https://www.hbm4eu.eu/).

ISCO-08: The International Standard Classification of Occupations 2008 (ISCO-08) is a four-level hierarchically structured classification that covers all jobs in the world. Developed with the benefit of accumulated national and international experience as well as the help of experts from many countries and agencies, ISCO-08 is fully supported by the international community as an accepted standard for international labour statistics (https://www.ilo.org/publications/international-standard-classification-occupations-2008-isco-08-structure).

PEH Data Platform: The Personal Exposure and Health (PEH) Data Platform was developed during the HBM4EU project and currently hosts the data from the HBM4EU Aligned Studies and the MoM-study (methylmercury-control in expectant mothers through suitable dietary advice for pregnancy). The platform will be expanded with new data generated under PARC (https://hbm.vito.be/peh-data-platform).

Introduction

Occupational exposure to some chemicals may be significantly higher than general population exposure. This is seen as elevated exposure biomarkers levels when biomonitoring studies are performed. Adult general population surveys may include individuals who are also occupationally exposed to specific chemicals like, for example, workers from metal-based industries, construction workers exposed to different metals or organic compounds (like bisphenols, phthalates or flame retardants), transport sector workers exposed to polycyclic aromatic hydrocarbons (PAHs), cleaners and nurses exposed to substances used in cleaning products and disinfectants, or e.g., cashiers exposed to bisphenols via thermal papers.

If information on occupation is appropriately collected in general population biomonitoring studies, it might be possible to extract information on the specific exposure of some common occupational groups and to analyze if it differs from the exposure of the rest of the population and to identify the potential contribution of these exposures to the general population levels. In addition, analysis of occupational information of most highly exposed individuals may provide valuable indications on potential occupational exposures which merit further investigation.

Within previous project "European Human Biomonitoring Initiative" (HBM4EU), detailed questionnaires to collect background information from the general population study participants were developed (González-Alzaga *et al.* 2022). The basic questionnaire contained information on the occupation and substance specific questionnaires included lists of occupational tasks where exposure may potentially occur according to the existing knowledge. Thus, these aligned HBM4EU studies which used HBM4EU questionnaires could include adequate information allowing identification of some specific occupational groups. It is, however, unsure if the numbers of individuals within different occupational groups are sufficient to identify potential occupational exposure. Even if numbers of individuals in specific occupational groups might be low for a proper exposure assessment, the data may still provide indications on potential occupational exposure when the higher end of the general population range is evaluated. In addition to HBM4EU aligned studies using HBM4EU questionnaires, also earlier general population studies include information on the occupation of the participants and could be used for the evaluation of occupational exposures. Evaluation of the general population data includes also the evaluation of the occupational groups most widely represented in these data sets.

Objective

The main objective of this project was to investigate if it is possible to identify occupationally exposed groups from the general (adult) population studies. This was done for selected HBM4EU priority chemicals, which were cadmium, chromium, PAHs and bisphenols.

The project was designed as a feasibility study with limited duration and resources. The main output is a review and recommendations on the use of occupation-related information from general population studies:

- Is it possible to identify some occupational groups and their exposure from the general population data? How much occupational exposure may contribute to explain the highest percentiles of exposure values in general population surveys?
- How should information on occupations be analyzed in general population studies?
- Can analysis of population surveys be used to screen possible less well-known occupational exposures?

In addition, the project aims to provide recommendations for future general population studies for the collection of data relevant for the identification of occupational exposure from general population data.

Materials and methods

Selection of example chemicals

Cadmium, chromium, bisphenols (bisphenol A, F and S), PAHs (pyrene and benzo[a]pyrene) were selected for the evaluation because they were priority chemicals in the HBM4EU study, The selected chemicals were analysed in the HBM4EU Aligned Studies, and they also have occupational relevance. A brief description of each chemicals follows.

Cadmium:

There are many sources of occupational exposure to cadmium (CAS No: 7440-43-9). Cadmium is a by-product of the zinc and lead industries and is present in certain metal alloys. The manufacture of certain lead compounds, such as lead oxide, can generate exposure to cadmium. Additionally, cadmium is extensively employed in the industry of batteries manufacture such as cadmium/nickel and silver/zinc ones. Moreover, the paint industry also uses cadmium-based pigments, and this metal and its derivatives are also utilized in the porcelain, surface treatment and plastics industries.

Recognized as carcinogenic, mutagenic, and reprotoxic, cadmium causes kidney damage and bone fragility in humans with prolonged chronic exposure.

Urinary cadmium, whatever the time of sampling, is the first indicator to be used in long-term risk management, as it mainly reflects chronic exposure and body burden. There is a correlation between urinary cadmium levels, the intensity of exposure and the risk of kidney damage, as assessed by the elevation of tubular damage markers.

Chromium:

Hexavalent chromium (Cr(VI) (CAS No: 18540-29-9) and its compounds (e.g. calcium chromate, potassium chromate, sodium chromate, zinc chromate, chromic acid, chromium trioxide, and ammonium chromate) have been used in many uses because of their properties related to hardness, durability and corrosion-resistance (NIOSH 2013; den Braver-Sewradj *et al.* 2021). Although Cr(VI) has been earlier used in various products including various paint and primer pigments, graphic art supplies, fungicides, corrosion inhibitors and wood preservatives (NIOSH, 2013), in Europe restrictions and the recent authorization of Cr(VI) compounds have limited its use. Therefore, the main use of Cr(VI) compounds nowadays in EU is related to metal or plastic surface treatment activities. However, occupational exposure to Cr(VI) occurs also in welding, stainless steel manufacturing and other types (hot) processes involving stainless steel and other metal alloys that contain chromium. In these activities, Cr(VI) is formed during the process from metallic chromium.

Industries where exposure occurs are the functional plating sector, steel, shipyards, construction, concrete industry and shops for repair and painting of auto bodies, trucks, trains and airplanes. Occupational exposure to the highest concentrations of Cr(VI) compounds can be experienced at electroplating, welding and painting industries (Santonen *et al.* 2022). The workers manufacturing chromium compounds, ferrochromium, chromate or chromate pigments are also exposed to Cr(VI) (Langard, Costa 2015).

Cr(VI) compounds related risks for human health range from skin irritation to DNA damage and cancer dependent on exposure level and duration (Tumolo *et al.* 2020). Cr(VI) and its compounds is a known carcinogen that may cause lung cancer in humans (IARC 2012). There is some evidence of a positive association between Cr(VI) compounds and nose and nasal sinus cancer in humans (IARC 2012; den Braver-Sewradj *et al.* 2021). Other cancers of the respiratory tract and the gastrointestinal tract can also be of concern (ECHA 2013; Deng *et al.* 2019). Occupational exposure to Cr(VI) can cause asthma, allergic dermatitis. There is evidence of an association between Cr(VI) compounds and effects on reproduction (low birth weight, low birth length) (Michael *et al.* 2022).

Chromium in urine is the primary and standard method for biomonitoring exposure to chromium (Santonen *et al.* 2022). However, urinary chromium analysis is not specific for Cr(VI) as exposure to the less toxic Cr(III) can also affect urinary chromium levels. A chromium test in plasma and red blood cells can be additionally performed (Paustenbach *et al.* 1997). The red blood cell (RBC) chromium analysis has been suggested as a more specific method to indicate exposure to Cr(VI), but it is not a commonly used method (Ndaw *et al.* 2022).

Bisphenols:

Bisphenols (A, S and F) are synthetic chemicals mainly used in the production of polycarbonates and epoxy resins. These compounds are found in the electronic equipment industry, food packaging, thermal papers, paints and varnishes. Occupational exposure has been observed in the manufacturing of plastics, epoxy resins, thermal papers, paints and among cashiers (Bousoumah *et al.* 2021). Bisphenols S and F have been employed for several years as alternatives to bisphenol A (BPA). EU has banned the use of bisphenol A in thermal papers used in cash receipts since January 2020. Companies have often used bisphenol S (BPS) to replace BPA in thermal paper.

Bisphenol A is defined by the World Health Organization (WHO) as an endocrine disrupter (WHO/UNEP 2013), “suspected reproductive toxicant” and classified as a “substance of very high concern of Very High Concern” by the European Chemicals Agency (ECHA), and is suspected of being associated with numerous pathologies (diabetes, obesity, cardiovascular, respiratory and kidney diseases, cancer). Data on bisphenols S and F are still lacking; however, some studies show that they play an endocrine-disrupting role similar to BPA.

In the body, bisphenols are present in both free and conjugated form (the metabolized form of bisphenols that reflects internal exposure). The measurement of total bisphenols in urine corresponds to the sum of the concentrations conjugated and free bisphenols in the biological samples analyzed.

PAHs:

PAHs is a large group of more than 100 chemicals formed during the incomplete burning of oil, gas, coal, garbage, and other organic substances such as tobacco and charbroiled meat (CDC 2024).

Occupational exposure to PAHs is experienced through inhalation and dermal contact. Industries that involve the combustion and pyrolysis of coal, the production and use of coal-derived products (coal tar and coal tar-derived products) are the sources of exposure to PAHs at workplaces. Workers at coal-gasification sites, smokehouses, coal-tarring facilities, waste incinerators, the plants producing coal-tar, coking, bitumen and aluminum, are exposed to PAHs. Occupational exposure to PAHs occurs in industries, such as mining, oil refining, metalworking, chemical production, transportation, and the electrical industry (Vanrooij *et al.* 1992).

Of the 60 PAHs reviewed by the IARC experts, only one, benzo[a]pyrene, is classified as a human carcinogen (Group 1) that can cause lung cancer. Meanwhile, cyclopenta[*cd*]pyrene, dibenz[*a,h*]anthracene, and dibenzo[*a,l*]pyrene, which are classified as *probably carcinogenic to humans* (Group 2A), and benz[*j*]aceanthrylene, benz[*a*]anthracene,

benzo[*b*]fluoranthene, benzo[*j*]fluoranthene, benzo[*k*]fluoranthene, benzo[*c*]phenanthrene, chrysene, dibenzo[*a,h*]pyrene, dibenzo[*a,i*]pyrene, indeno[1,2,3-*cd*]pyrene, and 5-methylchrysene, which are classified as *possibly carcinogenic to humans* (Group 2B) (IARC 2010). However, IARC has also classified several PAH mixtures and occupations with PAH exposure for their carcinogenicity. These include Coal tar pitch, coal tars and soots, Occupational exposures during coal gasification, Occupational exposures during coke production, Occupational exposures during coal-tar distillation, Occupational exposure as a chimney sweep, Occupational exposures during paving and roofing with coal-tar pitch and Occupational exposures during aluminium production, which have all been classified to IARC group 1. Some additional mixtures or occupations have been classified to group 2A and 2B (IARC 1985; IARC 2010; IARC 2013).

Long-term exposure to PAHs can affect pulmonary, gastrointestinal and renal systems, and the skin (ATSDR 2024). There is evidence on the impact of PAHs on reproduction of males (the reduction of sperm quality (Kakavandi *et al.* 2023; Mohammadzadeh *et al.* 2024).

PAHs are compounds with two or more benzene rings whose hydroxylated metabolites (OH-PAHs) are excreted in urine (Yang *et al.* 2021). Therefore, the assessment of human exposure to PAHs is based on urinary OH-PAH concentrations. PAHs metabolites in human urine can be used as biomarkers of internal dose to estimate recent exposure to PAHs (Strickland *et al.* 1996).

Study design

Study included the collection of existing general population data sets where the target chemicals (cadmium, chromium, bisphenols and PAHs) were analyzed from urine samples. Urine is the most suitable matrix to study occupational exposure to these chemicals. Also, blood cadmium was analysed in only one data set. However, we did not use that data because blood cadmium is not a good biomarker for occupational cadmium exposure, as smoking strongly influences the results. Other target chemicals were not analysed in blood samples. Only data sets concerning adults were included (both women and men). Children and teenagers were excluded.

All data sets were coded according to the 'International Standard Classification of Occupations (ISCO-08)' for classification of occupations. Those occupations where potential occupational exposure to target chemicals is expected to take place were recognized. Thereafter the experimental data of those occupations were combined for each target chemical and compared to the data of the rest of the general population.

Descriptive statistics were calculated for each group of occupations and the rest of the general population. Statistical tests were applied to analyze if there was any statistical difference between the potentially occupationally exposed and the rest of the general population.

The illustration of the study process is given in Figure 1.

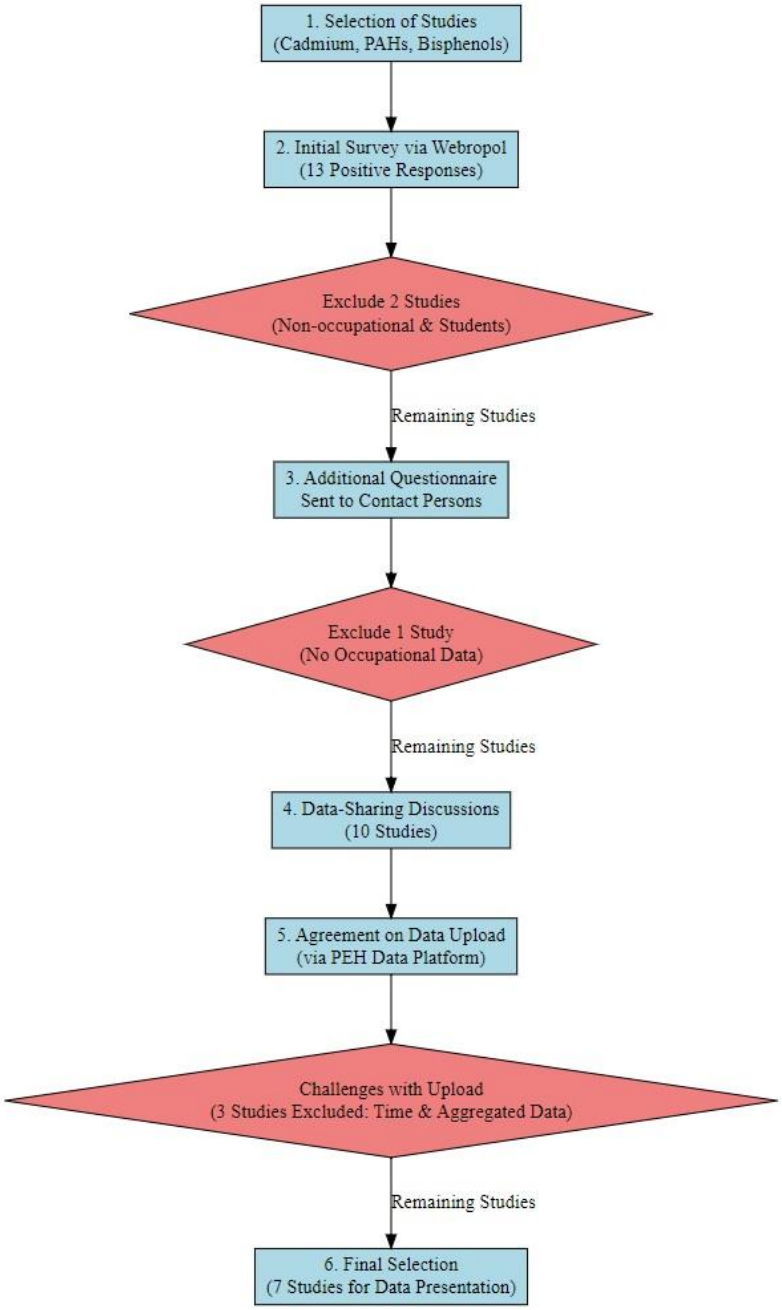

Figure 1. Process description (flow chart).

Identification of the applicable data sets and data sharing

Potential biomonitoring studies investigating cadmium, PAHs and bisphenols were selected from the Information Platform for Chemical Monitoring (IPCHEM, https://ipchem.jrc.ec.europa.eu/). Urinary chromium was added at a later stage. An international Webropol Survey and Reporting platform (https://webropol.com/) was applied to send a questionnaire link via e-mail to 45 contact persons of the studies from 32 institutes (Appendix 1). The survey also asked whether other metals were analyzed in the study in question. The survey received positive responses from 13

institutes (this is 41% of the institutes to which the invitation was sent). At this point, two studies were excluded (one with non-occupationally exposed participants only, the other with 24-year-old students only). An additional questionnaire was sent to the contact persons of other studies (Appendix 2). At this stage, one study was excluded because the study did not have information on the occupation of the participants. With the remaining 10 studies, further discussions about data sharing were initiated.

The research group decided that information sharing will be handled through the Personal Exposure and Health (PEH) Data Platform (https://hbm.vito.be/peh-data-platform) hosted by VITO, Belgium. Of the ten data sets, four had already been uploaded to the PEH Data Platform. Only some additional information still needed to be completed to the uploaded data sets (e.g., urine chromium results and ISCO-08 codes). The contact persons of the other studies agreed to upload the data of their studies to the PEH Data Platform, except for one study. For the study in question, an agreement was made on bilateral data transfer.

Uploading research data to the PEH Data Platform was a slow process and along the way it became apparent that the people responsible for two studies unfortunately did not have time to upload their data to the data platform. At this stage, it also became apparent that in the case of one study, there was no possibility to share the data of individual subjects (aggregated data only). Thus, these three studies were excluded. The remaining seven studies are presented in the following section.

Description of selected data sets

Table 1 presents the seven data sets included in this study. Six of them were from the PEH Data Platform and the remaining one was delivered via bilateral data transfer (HBM-LT).

Table 1. Selected final data sets.

Study name	Country	Sample collection year(s)	Chemicals analyzed			
			Cd	Cr	Bisphenol(s)	PAH(s)
BIOAMBIENT.ES	Spain	2009—2010	x			x
DIET_HBM	Island	2019—2021	x		x	x
ESTEBAN	France	2014—2016	x	x	x	x
HBM-LT	Lithuania	2020—2021	x			
HBMWal1_Adults	Belgium	2019—2020	x	x	x	x
IBS	Israel	2011			x	x
INSEF-ExpoQuim*	Portugal	2019—2022	x		x	x

*Unfortunately, this study was not ready for download from the PEH Data Platform before the statistical analyses of this report were completed.

Study descriptions

BIOAMBIENT.ES is a nationwide cross-sectional study, with a stratified cluster sampling designed to cover all geographical areas, sex and occupational sectors, and aimed to obtain a representative sample of the Spanish workforce. Participants were recruited among people residing in Spain for at least five years, which underwent their annual occupational medical check-up in the health facilities of the Societies for Prevention of IBERMUTUAMUR,

MUTUALIA, MCPREVENCIÓN, MUGATRA, UNIMAT PREVENCIÓN, and PREVIMAC between March 2009 and July 2010.

A total of 1,892 participants fulfilled the inclusion criteria, provided biological samples (1,880 blood, 1,770 urine, and 577 hair), and completed a brief self-administered epidemiological questionnaire on environmental and lifestyle exposures. Additionally, clinical information from participant's health exams was obtained. The list of biomarkers analyzed is available in Pérez-Gómez et al. (Pérez-Gómez *et al.* 2013). This project will provide a first overview of the body burden of selected pollutants in a representative sample of the Spanish-occupied population. This information will be useful to establish reference values of the studied population and, eventually, to evaluate temporal trends and the effectiveness of environmental and health policies.

DIET_HBM study: The samples are from the Icelandic National Dietary Survey conducted in 2019—2021. 200 participants from all over the country were contacted for dietary assessment and biomonitoring.

The dietary assessment consisted of two 24-h dietary recalls and a short food frequency questionnaire (FFQ) for common food groups. The two 24-h recalls were conducted via phone calls by trained interviewers on two non-consecutive days covering both weekdays and weekends. This sampling design delivers a more detailed information on all food, beverages and dietary supplements consumed on a given day by respondents compared to using a FFQ (EFSA 2009). Participants also answered several questions encompassing demographic details, lifestyle, and health-related factors. In addition, during the telephone interview, information on sociodemographic characteristics, education, lifestyle and health was recorded.

Urine, blood and serum were collected. Bisphenols, PAH and Cadmium were analyzed in the urine samples according to HBM4EU protocol. Later analysis of Acrylamide, Mycotoxin and Pesticides was added.

Esteban is a cross-sectional study of the general population living in mainland France aged between 6 and 74 years old. It was conducted between April 2014 and March 2016. In total, 2503 adults (18—74 years old) and 1104 children (6—17 years old) were included during four different periods, to take seasonal exposure variation into account.

The study collected data on health, nutrition, exposure to chemicals, and socio-demographic characteristics with the aid of two interview-based questionnaires, four self-administered questionnaires, a 24h dietary recall, and analysis of fasting biological samples (blood, urine, and hair). To ensure relevance of the results, participants were instructed not to consume fish or shellfish in the three days preceding the examination, and not to smoke in the preceding two hours of sampling collection. Urine samples were collected by participants upon waking (i.e., first morning urine).

The list of biomarkers analyzed is available in detail elsewhere (Fillol *et al.* 2014).

As the required volume of urine was not available for all Esteban participants, and because of the cost of performing the analyses, not all substances were measured for all the participants. Subsamples of participants were randomly drawn in order to analyze a series of biomarkers in their biological matrices.

HBM-LT is a cross-sectional survey of adults randomly selected in the five largest cities of Lithuania (Vilnius, Kaunas, Klaipėda, Šiauliai and Alytus) and their surrounding districts in 2020—2021. The study included 225 adults (101 men and 124 women) aged 18 and over.

All individuals were interviewed by trained interviewers used a structured questionnaire to obtain information on demographic and socioeconomic characteristics, medical history, and lifestyle characteristics (diet, smoking, alcohol use and physical activity).

Cadmium in urine was measured by ICP-MS. Urinary cadmium concentration was adjusted by urinary creatinine.

Since 2019, the Walloon Government decided to set up an extended human biomonitoring program, named **BMH-Wal**. BMH-Wal program aims to assess and monitor exposure of the Walloon population, Southern part of Belgium, to hazardous chemicals such as pesticides, endocrine disruptors, trace metals, and to get reference values. The 1st phase, BMH-Wal1, was conducted between 2019 and 2020 and focused on young adults (20 - 39 years old). A total of 261 young adults were included in the study.

The study collected data on health, nutrition, exposure to chemicals, and socio-demographic characteristics with the aid of a self-administered questionnaires, 24h and 72h dietary recalls, and analysis of biological samples (blood and urine). Urine samples were collected by participants upon waking (i.e., first morning urine). The list of biomarkers measured in the different biological matrices is available in detail in the study report (BMH-Wal 2024).

IBS was a cross-sectional study of the general population living in Israel aged between 20 and 73 years old. It was conducted between February and June 2011. In total, 250 adults were included. The study collected data on health, nutrition, exposure to chemicals, and socio-demographic characteristics with the aid of a 24-hour dietary recall, an adapted food frequency questionnaire, a demographic questionnaire and a health/lifestyle questionnaire which included questions on occupation. Participants were not targeted for specific exposure scenarios (suspected geographic hotspots or occupation). Spot urine samples were collected at the time of interview. The list of biomarkers analyzed included bisphenol A (BPA), organophosphate (OP) pesticide metabolites, phthalate metabolites, cotinine, and polycyclic aromatic hydrocarbons (PAHs). More information on the study is available in detail (Berman *et al.* 2013). Findings predictors of BPA exposure (Berman *et al.* 2014) and PAHs (Levine *et al.* 2015) are available.

INSEF-ExpoQuim study from Portugal failed to meet the deadline for uploading of ISCO-coded results to the PEH Data Platform and was not included in the current statistical analyses. It can be, however, included for further analyses performed for future scientific publication.

Selection of relevant ISCO-08 codes

In most general population studies, the occupational activity is only described by a job title in the language of the concerned country. Nevertheless, in order to take into account the influence of the occupational activity on exposure, it was necessary to harmonize and classify them according to a single classification system. The classification system International Standard Classification of Occupations (ISCO-08) was chosen.

Occupational activities involving the use or production of each compound of interest were listed, based on the literature and knowledge of potential occupational exposure. The corresponding ISCO-08 codes were subsequently manually extracted from the ICSO-08 exhaustive list (https://ilostat.ilo.org/methods/concepts-and-definitions/classification-occupation/). ISCO-08 codes were selected with a 4-digit precision level.

A list of relevant ISCO-08 codes was established individually for cadmium, chromium, bisphenols and PAHs (Appendix 3). The list was transferred to data owners in order to allow them to code their data sets accordingly. As it was a time-consuming procedure, the decision was taken to code only the occupational activities from the selected ISCO-08 code list (preferably with 4-digits). Nevertheless, many of the data sets were almost fully coded.

Data analysis

First, descriptive statistics were calculated separately for each ISCO-08 class and after this divided into three groups by whether the people whose work is defined into specific ISCO-08 codes are considered to be in particular risk of

work-based exposure to a specific chemical. These descriptive statistics were numbers of observations, arithmetic and geometric means, minima, maxima and medians as well as the 10th, 25th, 75th, 90th and 95th percentiles of the observed data distributions. After this, non-parametric tests were applied to test differences between the locations of the distributions between work-based exposure classes as well as smoking. In two-class tests, Mann—Whitney U and Brunner—Munzel tests were used. The Brunner—Munzel test is more accurate than Mann—Whitney test when n is small (as is often the case in this study). A one-tailed test, which specifically tests whether group one had larger results than group 2, was chosen because there was an emphasis on whether higher results could be observed in individuals for whom exposure could be work-based. P-values of <0.05 were considered statistically significant.

Test statistical results also include effect size. If differences are being tested between groups 1 and 2, the effect size is calculated as follows: we observe all combinations of an observation from group 1 and an observation from group 2. Then the effect size is the ratio of these pairs where the observation from group 1 is larger than the observation from group 2 plus half the ratio of pairs where the values of the observations in groups 1 and 2 are equal. Thus, this measure represents on a scale of [0,1] the relative number of observations where the observations from group 1 are higher than those of group 2. Both values close to zero and values close to one should be interpreted as the effect size of difference between the two groups being high whereas values around 0.5 imply low effect size.

Statistical software used: RStudio 2023.03.1+446 "Cherry Blossom" Release (6e31ffc3ef2a1f81d377eeccab71ddc11cfbd29e, 2023-05-09) for Windows. Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) RStudio/2023.03.1+446 Chrome/108.0.5359.179 Electron/22.0.3 Safari/537.36.

Regarding the data obtained from the PEH Data Platform, values below the limit of detection (LOD) or limit of quantification (LOQ) or between LOD and LOQ are imputed using a random single imputation using a censored log-normal distribution. The distribution based random single imputation technique is performed as follows: (i) Assume the data is log-normally distributed and left-censored. (ii) Use maximum likelihood estimation (MLE) to fit a log-normal distribution to the censored data. (iii) For each censored data point, sample a value from the fitted log-normal distribution. Sampling will be done in a range that is determined by a lower and upper bound (Hassen *et al.* 2024).

Results

The database obtained from the PEH Data Platform contains data for 5192 samples. Of these, 1892 samples were whole blood samples, the rest being urine samples (either first-morning-voids or random spot samples). As explained above, in this study we only considered urine samples. Not all the urine samples were analyzed for all chemicals of interest in this study (namely cadmium, chromium, bisphenols, and PAH metabolites) due to budget constraint issues. The bisphenols considered were bisphenol A (BPA), bisphenol F (BPF), and bisphenol S (BPS). Biomarkers of PAH exposure were 1-hydroxypyrene (1-Pyr; metabolite of pyrene) and hydroxybenzo[a] pyrene (OHBaP; metabolite of benzo[a]pyrene). Urinary bisphenol concentrations were total concentrations (i.e., free + conjugated). Total number of urinary results in each study are listed in Table 2.

Table 2. Total number of urinary results in each study.

Chemical/Study	BIOAMBIENT.ES	DIET_HBM	ESTEBAN	HBM-LT	HBMWal1_adults	IBS	Sum

Cadmium	1848	203	393	243	259	0	2946
Chromium	0	0	442	0	259	0	701
BPA	0	203	163	0	259	247	872
BPF	0	203	163	0	259	0	625
BPS	0	203	163	0	259	0	625
1-Pyr	991	203	201	0	259	243	1897
OHBaP	0	203	201	0	0	0	404

The database contains ISCO-08 codes either with 2, 3 or 4 digits (sometimes several codes were given but we only considered the highest (with more digits) ISCO-08 available). ISCO-08 codes were not given for all the samples. In this study we only included those urine samples which had both the ISCO-08 code (either with 2, 3, or 4 digits) and a creatinine adjusted analytical result. Table 3 shows the number of urinary results in each study where the ISCO-08 code is given. It needs to be noted that some of the studies included in this report were only coded for those occupations which were identified relevant for potential occupational exposure (see the list in Appendix 3).

Table 3. The number of urinary results in different studies. Only results with the ISCO-08 code are included.

Chemical/Study	BIOAMBIENT.ES	DIET_HBM	ESTEBAN	HBM-LT	HBMWal1_adults	IBS
Cadmium	1596	41	386	243	201	0
Chromium	0	0	435	0	201	0
BPA	0	41	160	0	201	23
BPF	0	41	160	0	201	0
BPS	0	41	160	0	201	0
1-Pyr	861	41	196	0	201	24
OHBaP	0	41	196	0	0	0

Table 4 presents the total number of urine samples for each chemical studied. As mentioned, only those samples were counted for which both the ISCO-08 codes and the creatinine adjusted results were available. Also, the number of samples below the LOQ are given in the table.

Table 4. The total number of urinary results for each chemical and the number of results below the LOQ. Only those urinary results where ISCO-08 code was available.

	Cd	Cr	BPA	BPF	BPS	1-Pyr	OHBaP
Total N	2467	636	425	402	402	1323	237
N <LOQ	70	211	71	141	127	290	235
% <LOQ	2.8	33.2	16.7	35.1	31.6	21.9	99.2

LOQ; limit of quantification.

Regarding hydroxybenzo[a]pyrene (OHBaP), the results of all but two samples were below the LOQ. This means that urinary OHBaP results were not further considered in this study.

The database contains 316 different ISCO-08 codes for which there are analytical results. The most common ISCO-08 codes were 4110 (General Office Clerks; 268 samples), 5419 (Protective Services Workers Not Elsewhere Classified; 90 samples), 9112 (Cleaners and Helpers in Offices, Hotels and Other Establishments; 78 samples), 2221 (Nursing Professionals; 59 samples), and 7231 (Motor Vehicle Mechanics and Repairers; 55 samples). 50 ISCO-08 codes with the most samples are listed in Appendix 4. It needs to be noted that different occupations were not randomly or similarly distributed between different studies. For example, the majority of ISCO-08 group 9112 (Cleaners and Helpers in Offices, Hotels and Other Establishments) came from the BIOAMBIENT.ES study. This may be due to the targeting of the original study and special characteristics of the regional/local business life.

As described above, we selected relevant occupations (ISCO-08 codes) for each chemical regarding potential occupational exposure (see Appendix 3). The same relevant ISCO-08 codes were selected for all three bisphenols, and also for both PAH biomarkers. The highest number of samples for selected relevant ISCO-08 codes are given in Table 5. A full list of samples for each relevant ISCO-08 code is shown in Appendix 5.

Table 5. Highest number of samples (N) for selected relevant ISCO-08 codes (minimum 5 samples). A full list of relevant ISCO-08 codes and number of samples is available in Appendix 5.

Cadmium		
ISCO-08	**N**	**Occupations**
9112	77	Cleaners and Helpers in Offices, Hotels and Other Establishments
7231	55	Motor Vehicle Mechanics and Repairers
3322	39	Commercial Sales Representatives
2133	33	Environmental Protection Professionals
7123	29	Plasterers
1219	22	Business Services and Administration Managers Not Elsewhere Classified
7119	20	Building Frame and Related Trades Workers Not Elsewhere Classified
6113	19	Gardeners, Horticultural and Nursery Growers
7126	18	Plumbers and Pipe Fitters
7131	16	Painters and Related Workers
9211	16	Crop Farm Labourers
8189	15	Stationary Plant and Machine Operators Not Elsewhere Classified
3141	14	Life Science Technicians (excluding Medical)
3123	13	Construction Supervisors
8332	13	Heavy Truck and Lorry Drivers
7223	12	Metal Working Machine Tool Setters and Operators
7421	12	Electronics Mechanics and Servicers
8131	12	Chemical Products Plant and Machine Operators
2113	11	Chemists
2131	10	Biologists, Botanists, Zoologists and Related Professionals
7212	10	Welders and Flame Cutters
6114	8	Mixed Crop Growers

8122	8	Metal Finishing, Plating and Coating Machine Operators
2151	6	Electrical Engineers
3112	5	Civil Engineering Technicians
3139	5	Process Control Technicians Not Elsewhere Classified
5153	5	Building Caretakers
8111	5	Miners and Quarriers
Chromium		
ISCO-08	**N**	**Occupations**
2133	31	Environmental Protection Professionals
2330	24	Secondary Education Teachers
3141	7	Life Science Technicians (excluding Medical)
9333	6	Freight Handlers
9112	5	Cleaners and Helpers in Offices, Hotels and Other Establishments
Bisphenols		
ISCO-08	**N**	**Occupations**
5230	15	Cashiers and Ticket Clerks
Pyrene		
ISCO-08	**N**	**Occupations**
2133	32	Environmental Protection Professionals
7113	25	Stonemasons, Stone Cutters, Splitters and Carvers
7411	25	Building and Related Electricians
9112	23	Cleaners and Helpers in Offices, Hotels and Other Establishments
7231	22	Motor Vehicle Mechanics and Repairers
3322	21	Commercial Sales Representatives
9333	19	Freight Handlers
7123	14	Plasterers
7119	13	Building Frame and Related Trades Workers Not Elsewhere Classified
8219	13	Assemblers Not Elsewhere Classified
3141	12	Life Science Technicians (excluding Medical)
9313	9	Building Construction Labourers
7421	8	Electronics Mechanics and Servicers
3123	7	Construction Supervisors
7115	6	Carpenters and Joiners
7126	6	Plumbers and Pipe Fitters
8122	6	Metal Finishing, Plating and Coating Machine Operators
2151	5	Electrical Engineers
7212	5	Welders and Flame Cutters
7223	5	Metal Working Machine Tool Setters and Operators
8332	5	Heavy Truck and Lorry Drivers

Benzo[a]pyrene		
ISCO-08	**N**	**Occupations**
2151	5	Electrical Engineers

Data was divided into the following groups: all observations, relevant ISCO-08 codes, semi-relevant ISCO-08 codes, and non-relevant ISCO-08 codes. Description of these groups are given in Table 6.

Table 6. Description of the selected data groups.

Group	Description
All observations	Includes all samples for which there was both the ISCO-08 code and the creatinine adjusted analytical result.
Relevant ISCO-08	Results of those samples, which have a relevant ISCO-08 code with 4-digits (see Appendix 3).
Semi-relevant ISCO-08	Results of those samples, which have a relevant ISCO-08 code but with 2 or 3 digits. 2- or 3-digit codes are not specific enough to indicate potential occupational exposure. It is, however, possible that this group included some occupations where occupational exposure may take place.
Non-relevant ISCO-08	Results of all other samples except those of the relevant and semi-relevant ISCO-08 codes.

Table 7 shows the distribution of semi-relevant ISCO-08 code samples among six different studies.

Table 7. Distribution of semi-relevant ISCO-08 samples among different studies.

Study name	Cadmium	Chromium	BPA	BPF	BPS	1-Pyr
	N (%*)	**N (%*)**	**N (%*)**	**N (%*)**	**N (%*)**	**N (%*)**
All	132	119	16	11	11	110
BIOAMBIENT.ES	58 (44)	-	-	-	-	38 (35)
DIET_HBM	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)
ESTEBAN	67 (51)	119 (100)	11 (69)	11 (100)	11 (100)	48 (44)
HBM-LT	7 (5)	-	-	-	-	-
HBMWal1_Adults	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
IBS	-	-	5 (31)	-	-	24 (22)

*Percentage of all semi-relevant ISCO-08 samples for the given biomarker.

The descriptive statistics of all results of relevant ISCO-08 4-digit codes for each chemical are given in Table 8. Table 8 also includes the descriptive statistics of all samples (named all observations), those of semi-relevant ISCO-08 codes and those samples of which ISCO-08 codes are not relevant for the given chemical (named non-relevant ISCO-08). Percentiles lower than P50 are not given because for many chemicals they were below the LOQ (see Table 3).

Table 8. Descriptive statistics of the data of all observations, relevant ISCO-08 codes, semi-relevant ISCO-08 codes, and non-relevant ISCO-08 codes. Results are given in unit of µg/g creatinine.

Cadmium							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	2467	0.209	0.220	0.379	0.619	0.863	12.616
Relevant ISCO-08	575	0.200	0.206	0.366	0.572	0.723	2.759
Semi-relevant ISCO-08	132	0.236	0.257	0.436	0.621	0.741	1.862
Non-relevant ISCO-08	1760	0.210	0.222	0.379	0.642	0.897	12.616
Chromium							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	636	0.160	0.374	0.778	1.369	2.007	12.226
Relevant ISCO-08	131	0.047	0.040	0.400	0.792	1.004	5.272
Semi-relevant ISCO-08	119	0.606	0.606	1.022	1.755	2.238	5.993
Non-relevant ISCO-08	386	0.161	0.375	0.792	1.396	2.140	12.226
Bisphenol A							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	425	1.181	1.289	2.535	5.169	9.274	91.716
Relevant ISCO-08	21	1.635	1.825	2.764	3.212	3.270	5.336
Semi-relevant ISCO-08	16	1.945	2.231	2.636	4.886	7.030	9.418
Non-relevant ISCO-08	388	1.137	1.232	2.478	5.274	9.418	91.716
Bisphenol F							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	402	0.137	0.182	0.382	0.847	1.067	9.624
Relevant ISCO-08	21	0.141	0.235	0.698	1.337	1.371	2.576
Semi-relevant ISCO-08	11	0.276	0.281	0.420	0.500	1.073	1.646
Non-relevant ISCO-08	370	0.134	0.178	0.368	0.816	1.030	9.624
Bisphenol S							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	402	0.196	0.220	0.578	1.575	2.618	324.981
Relevant ISCO-08	21	0.057	0.162	0.273	0.885	1.243	1.557

Semi-relevant ISCO-08	11	0.302	0.300	0.347	0.637	4.948	9.259
Non-relevant ISCO-08	370	0.208	0.221	0.590	1.803	2.690	324.981
1-Pyr							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	1323	0.108	0.121	0.235	0.422	0.655	4.446
Relevant ISCO-08	339	0.113	0.124	0.260	0.452	0.671	2.806
Semi-relevant ISCO-08	110	0.128	0.128	0.210	0.373	0.639	4.446
Non-relevant ISCO-08	874	0.105	0.120	0.232	0.422	0.643	3.729

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Regarding median concentrations, only for BPA and BPF the medians are clearly higher for the group of relevant ISCO-08 codes when compared to the respective medians of non-relevant ISCO-08 codes.

Table 9 presents statistical comparison of different groups. A one-tailed test, which specifically tests whether group one had larger results than group 2, was chosen because there was an emphasis on whether higher results could be observed in individuals for whom exposure could be work-based.

Table 9. Statistical comparison of the results of relevant ISCO-08 codes, semi-relevant ISCO-08 codes, and non-relevant ISCO-08 codes. One-tailed test results are shown. P-values <0.05 are bolded.

Cadmium		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=575)	Non-relevant ISCO-08 (N=1760)	0.487	0.834	0.836
Relevant ISCO-08 (N=575)	Semi-relevant ISCO-08 (N=132)	0.446	0.973	0.971
Semi-relevant ISCO-08 (N=132)	Non-relevant ISCO-08 (N=1760)	0.541	0.059	0.060
Chromium		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=131)	Non-relevant ISCO-08 (N=386)	0.341	0.999	0.999
Relevant ISCO-08 (N=131)	Semi-relevant ISCO-08 (N=119)	0.168	1.000	1.000
Semi-relevant ISCO-08 (N=119)	Non-relevant ISCO-08 (N=386)	0.664	**<0.001**	**<0.001**
BPA		**Mann—Whitney**		**Brunner—Munzel**

Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=21)	Non-relevant ISCO-08 (N=388)	0.608	**0.048**	**0.019**
Relevant ISCO-08 (N=21)	Semi-relevant ISCO-08 (N=16)	0.494	0.530	0.523
Semi-relevant ISCO-08 (N=16)	Non-relevant ISCO-08 (N=388)	0.636	**0.033**	**0.010**
BPF		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=21)	Non-relevant ISCO-08 (N=370)	0.536	0.291	0.332
Relevant ISCO-08 (N=21)	Semi-relevant ISCO-08 (N=11)	0.450	0.680	0.682
Semi-relevant ISCO-08 (N=11)	Non-relevant ISCO-08 (N=370)	0.631	0.069	**0.030**
BPS		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=21)	Non-relevant ISCO-08 (N=370)	0.378	0.970	0.948
Relevant ISCO-08 (N=21)	Semi-relevant ISCO-08 (N=11)	0.346	0.922	0.936
Semi-relevant ISCO-08 (N=11)	Non-relevant ISCO-08 (N=370)	0.540	0.318	0.273
1-Pyr		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08 (N=339)	Non-relevant ISCO-08 (N=874)	0.510	0.289	0.290
Relevant ISCO-08 (N=339)	Semi-relevant ISCO-08 (N=110)	0.484	0.691	0.701
Semi-relevant ISCO-08 (N=110)	Non-relevant ISCO-08 (N=874)	0.525	0.196	0.175

Basically, the only case when relevant ISCO-08 results were significantly higher than the results of non-relevant ISCO-08 results is for BPA (p-values 0.048 and 0.019 for the Mann—Whitney and Brunner—Munzel tests, respectively). It should be noted, however, that the number of relevant ISCO-08 for BPA was 21, which was rather low number for a statistical comparison (the respective number of non-relevant ISCO-08 samples was 388). Most of the relevant ISCO-08 code samples for BPA were from cashiers and ticket clerks (see Appendix 5). Interestingly, also the BPA results of semi-relevant ISCO-08 group were significantly higher than the results of non-relevant ISCO-08 group (p-values 0.033 and 0.010 for the Mann—Whitney and Brunner—Munzel tests, respectively). However, the results of relevant ISCO-08 were not higher than the results of semi relevant ISCO-08. This result may indicate that semi-relevant ISCO-group also included potentially occupationally exposed.

We grouped relevant ISCO-08 and semi-relevant ISCO-08 (N=37) and tested if this combined group had higher results than the non-relevant ISCO-08 group. The resulted p-values were 0.008 (effect size 0.620; Mann—Whitney)

and 0.001 (Brunner—Munzel). Accordingly, the combined group had significantly higher values than the non-relevant ISCO-08 group. However, it should be noted that the concentration levels of BPA were still quite low when considering the P95 and maximum levels (see Table 8).

For cadmium, chromium, BPF, BPS, and 1-Pyr, the results of relevant ISCO-08 were not higher than the respective results of non-relevant ISCO-08 group. On the other hand, the chromium results of the semi-relevant ISCO-08 group were significantly higher than the results of the non-relevant ISCO-08 group. When combining relevant ISCO-08 and semi-relevant ISCO-08 and testing against the non-relevant ISCO-08 group, the resulted p-values did not indicate higher results of the combined group (i.e., $p>0.05$).

Analysis of the highest exposures among the "non-relevant ISCO-08" group

It is also of interest to see if the group of non-relevant ISCO-08 could contain potentially occupationally exposed, i.e., to check if we have missed some relevant ISCO-08 codes. The list of those ISCO-08 codes of which the urinary concentration exceeded the P95 value of the non-relevant ISCO-08 group are listed in Appendix 6. As can be seen, the resulted ISCO-08 codes were quite scattered between the different occupations. Only few ISCO-08 codes were identified where occupational exposure could be clearly considered to explain the elevated levels observed for the given chemical. This suggests that the identification of relevant ISCO-08 codes that was made in the project was rather comprehensive. However, among these highest 5 percentile results, there were three subjects representing following occupations (1 subject/ISCO-08 code): Cooks (ISCO-08 5120), Stationary Plant and Machine Operators Not Elsewhere Classified (ISCO-08 8189), Locomotive Engine Drivers (ISCO-08 8311). It may be that also in these occupations occupational exposure to PAHs (pyrene) may have occurred. Since these were representing on total of three subjects, they do not have significant effect on the results of the statistical analyses.

Effect of smoking

Smoking is known to affect the urinary levels of cadmium and 1-hydroxypyrene in urine. Table 10 shows the descriptive statistics of urinary cadmium for all results, the results of smokers and non-smokers.

Table 10. Descriptive statistics of urinary cadmium regarding all results, the results of smokers and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	2467	0.209	0.220	0.379	0.619	0.863	12.616
Relevant ISCO-08	575	0.200	0.206	0.366	0.572	0.723	2.759
Semi-relevant ISCO-08	132	0.236	0.257	0.436	0.621	0.741	1.862

Non-relevant ISCO-08	1760	0.210	0.222	0.379	0.642	0.897	12.616
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	778	0.260	0.256	0.456	0.728	1.072	8.059
Relevant ISCO-08	211	0.261	0.272	0.467	0.655	0.865	2.759
Semi-relevant ISCO-08	22	0.307	0.319	0.490	0.706	0.965	1.225
Non-relevant ISCO-08	545	0.258	0.250	0.443	0.773	1.157	8.059
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	1679	0.189	0.205	0.341	0.541	0.759	12.616
Relevant ISCO-08	364	0.171	0.190	0.304	0.500	0.612	2.467
Semi-relevant ISCO-08	109	0.223	0.246	0.416	0.540	0.725	1.862
Non-relevant ISCO-08	1206	0.192	0.206	0.353	0.571	0.821	12.616

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Regarding median concentrations of smokers and non-smokers, the former had higher medians for all groups. However, there was no clear difference between relevant ISCO-08 and non-relevant ISCO-08 within smokers and non-smokers. Table 11 shows the statistical comparison of smokers and non-smokers for urinary cadmium results.

Table 11. Statistical comparison of urinary cadmium results of smokers and non-smokers. One-tailed test results are shown. P-values <0.05 are bolded.

		Mann—Whitney		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=211)	Relevant ISCO-08, non-smokers (N=364)	0.369	**<0.001**	**<0.001**
Semi-relevant ISCO-08, smokers (N=22)	Semi-relevant ISCO-08, non-smokers (N=109)	0.391	0.054	0.061
Non-relevant ISCO-08, smokers (N=545)	Non-relevant ISCO-08, non-smokers (N=1206)	0.416	**<0.001**	**<0.001**
Relevant ISCO-08, smokers (N=211)	Non-relevant ISCO-08, smokers (N=545)	0.509	0.355	0.354
Relevant ISCO-08, smokers (N=211)	Semi-relevant ISCO-08, smokers (N=22)	0.437	0.835	0.825
Semi-relevant ISCO-08, smokers (N=22)	Non-relevant ISCO-08, smokers (N=545)	0.574	0.119	0.122

Relevant ISCO-08, non-smokers (N=364)	Non-relevant ISCO-08, non-smokers (N=1206)	0.464	0.981	0.983
Relevant ISCO-08, non-smokers (N=364)	Semi-relevant ISCO-08, non-smokers (N=109)	0.415	0.996	0.995
Semi-relevant ISCO-08, non-smokers (N=109)	Non-relevant ISCO-08, non-smokers (N=1206)	0.549	**0.046**	**0.047**

As expected, smokers had significantly higher urinary cadmium results than non-smokers for both relevant ISCO-08 (p-values <0.001) and non-relevant ISCO-08 (p-values <0.001) groups. Statistically significantly higher result was not observed for the results of the semi-relevant ISCO-08 group (p-values 0.054 and 0.061).

A statistical comparison between different groups of smokers did not reveal higher results for relevant ISCO-08.

For non-smokers, the results of semi-relevant ISCO-08 group were significantly higher than the results of non-relevant ISCO-08 group although very scarcely (Mann—Whitney p-value 0.046). On the other hand, the results of relevant ISCO-08 were not significantly higher than the results of semi-relevant ISCO-08. Similarly, the results of relevant ISCO-08 were not significantly higher than the results of non-relevant ISCO-08. This indicates that the results of the different groups were overall close to each other. No specific reason for the observed statistically significantly higher levels in semi-relevant ISCO-08 non-smoker group compared to the non-relevant ISCO-08 non-smokers can be identified.

Table 12 shows the descriptive statistics of urinary 1-hydroxypyrene for all results, the results of smokers and non-smokers. It is seen that median results of smokers were higher than those of non-smokers. However, the medians of different groups of smokers and non-smokers were of very similar magnitude.

Table 12. Descriptive statistics of urinary 1-hydroxypyrene regarding all results, the results of smokers, and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	1323	0.108	0.121	0.235	0.422	0.655	4.446
Relevant ISCO-08	339	0.113	0.124	0.260	0.452	0.671	2.806
Semi-relevant ISCO-08	110	0.128	0.128	0.210	0.373	0.639	4.446
Non-relevant ISCO-08	874	0.105	0.120	0.232	0.422	0.643	3.729
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	416	0.188	0.207	0.371	0.643	0.790	4.446
Relevant ISCO-08	115	0.195	0.208	0.402	0.664	0.887	1.792
Semi-relevant ISCO-08	24	0.212	0.212	0.358	0.703	0.743	4.446

Non-relevant ISCO-08	277	0.184	0.203	0.367	0.598	0.742	3.133
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	902	0.084	0.093	0.177	0.325	0.439	3.729
Relevant ISCO-08	224	0.085	0.091	0.185	0.310	0.369	2.806
Semi-relevant ISCO-08	86	0.111	0.110	0.165	0.331	0.467	1.266
Non-relevant ISCO-08	592	0.080	0.091	0.173	0.326	0.455	3.729

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Table 13 shows the statistical comparison of smokers and non-smokers for urinary 1-hydroxypyrene results. The results of smokers were clearly higher than non-smokers for all groups (relevant, semi-relevant, and non-relevant ISCO-08).

However, when the smokers' results of relevant ISCO-08 were compared to the results of non-relevant ISCO-08 and to the results of semi-relevant ISCO-08, the results of relevant ISCO-08 were not statistically significantly higher.

Regarding non-smokers, the results of relevant ISCO-08 were not significantly higher than the results of non-relevant ISCO-08. Also, the results of relevant ISCO-08 were not significantly higher the results of semi-relevant ISCO-08. Interestingly, the results of semi-relevant ISCO-08 were significantly higher than the results of non-relevant ISCO-08. There is no clear explanation for this difference.

Table 13. Statistical comparison of urinary 1-hydroxypyrene results of smokers and non-smokers. One-tailed test results are shown. P-values <0.05 are bolded.

		Mann—Whitney		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=115)	Relevant ISCO-08, non-smokers (N=224)	0.281	**<0.001**	**<0.001**
Semi-relevant ISCO-08, smokers (N=24)	Semi-relevant ISCO-08, non-smokers (N=86)	0.305	**0.002**	**0.004**
Non-relevant ISCO-08, smokers (N=227)	Non-relevant ISCO-08, non-smokers (N=592)	0.283	**<0.001**	**<0.001**
Relevant ISCO-08, smokers (N=115)	Non-relevant ISCO-08, smokers (N=277)	0.519	0.281	0.286
Relevant ISCO-08, smokers (N=115)	Semi-relevant ISCO-08, smokers (N=24)	0.495	0.530	0.528
Semi-relevant ISCO-08, smokers (N=24)	Non-relevant ISCO-08, smokers (N=277)	0.521	0.368	0.375
Relevant ISCO-08, non-smokers (N=224)	Non-relevant ISCO-08, non-smokers (N=592)	0.506	0.398	0.398

Relevant ISCO-08, non-smokers (N=224)	Semi-relevant ISCO-08, non-smokers (N=86)	0.437	0.958	0.967
Semi-relevant ISCO-08, non-smokers (N=86)	Non-relevant ISCO-08, non-smokers (N=592)	0.568	**0.021**	**0.011**

Other studied chemicals (chromium and bisphenols) are not supposed to be strongly affected by smoking status although some statistical differences were observed (see Appendix 7). However, the low number of samples for smokers prevented doing more detailed conclusions for bisphenols.

Results of detailed analysis of relevant ISCO-08

So far, the results have been processed at the group level categorized as relevant, semi-relevant, and non-relevant ISCO-08 groups. It is interesting to see if there are individual occupations where occupational exposure may have occurred. We selected the results of those relevant ISCO-08 where the number of urinary results was ≥20 (see Appendix 5) and made statistical comparison of their results compared to the results of non-relevant ISCO-08. Only for cadmium, chromium, and 1-hydroxypyrene there were ≥20 urinary results. Table 14 presents the results of the statistical tests.

Table 14. Statistical comparison of individual relevant ISCO-08s and non-relevant ISCO-08. One-tailed test results are shown. P-values <0.05 are bolded.

Cadmium		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
1219 (N=22)	Non-relevant ISCO-08 (N=1760)	0.517	0.395	0.393
2133 (N=33)	Non-relevant ISCO-08 (N=1760)	0.340	0.999	0.999
3322 (N=39)	Non-relevant ISCO-08 (N=1760)	0.510	0.419	0.413
7119 (N=20)	Non-relevant ISCO-08 (N=1760)	0.481	0.618	0.615
7123 (N=29)	Non-relevant ISCO-08 (N=1760)	0.478	0.659	0.656
7231 (N=55)	Non-relevant ISCO-08 (N=1760)	0.431	0.959	0.959
9112 (N=77)	Non-relevant ISCO-08 (N=1760)	0.660	**<0.001**	**<0.001**
Chromium		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
2133 (N=31)	Non-relevant ISCO-08 (N=386)	0.190	1,000	1.000

2330 (N=24)	Non-relevant ISCO-08 (N=386)	0.160	1,000	1.000
1-Pyr		**Mann—Whitney**		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
2133 (N=32)	Non-relevant ISCO-08 (N=874)	0.424	0.929	0.938
3322 (N=21)	Non-relevant ISCO-08 (N=874)	0.523	0.357	0.385
7113 (N=25)	Non-relevant ISCO-08 (N=874)	0.504	0.475	0.476
7231 (N=22)	Non-relevant ISCO-08 (N=874)	0.535	0.287	0.287
7411 (N=25)	Non-relevant ISCO-08 (N=874)	0.470	0.694	0.717
9112 (N=23)	Non-relevant ISCO-08 (N=874)	0.550	0.207	0.236

As seen in Table 14, only one relevant ISCO-08 for cadmium resulted significantly higher results when compared to cadmium results of non-relevant ISCO-08. Namely ISCO-08 code 9112 (Cleaners and Helpers in Offices, Hotels and Other Establishments).

It is noted that of those 77 results, 71 were from the BIOAMBIENT.ES study (Spain), four from the ESTEBAN study (France), and two from the HBM-LT study (Lithuania). Because there might be differences in background levels of cadmium in different countries, we tested if this was the explanation for such result.

This appears not to be the case, since the results of 71 samples from the BIOAMBIENT.ES study (Spain) with ISCO-08 code 9112 were significantly higher than the results of non-relevant ISCO-08 from the BIOAMBIENT.ES study (N=1115). Both Mann—Whitney and Brunner—Munzel tests resulted p-values of <0.001 (1-tail test, effect size 0.689) indicating that the higher results of ISCO-08 9112 were not because of higher background levels of cadmium in Spain.

Another explanation might be smoking. The percentage of smokers in Spanish ISCO-08 code 9112 group was 35.2, while the respective percentage of non-relevant ISCO-08 was 36.2. So, they were quite equal.

Statistical test between the BIOAMBIENT.ES cohort ISCO-08 code 9112 smokers (N=25) vs. non-smokers (N=46) showed no higher results in smokers (1-tail; p-value 0.128 (effect size 0.583; Mann—Whitney) and p-value 0.136 (Brunner—Munzel)) whereas the respective test results between the BIOAMBIENT.ES study non-relevant ISCO-08 smokers (N=400) and non-smokers (N=703) showed clearly higher results in smokers [1-tail; p-value <0.001 (effect size 0.594; Mann—Whitney) and p-value <0.001 (Brunner—Munzel)].

Overall, these test results suggest that smoking is not explaining the higher results among Cleaners and Helpers in Offices, Hotels and Other Establishments (ISCO-08 9112). Accordingly, the urinary cadmium results of ISCO-08 9112 may indicate possible occupational exposure of this group of workers. It must be noted that ISCO-08 code 9112 includes not only ordinary cleaners etc. but also, e.g., building cleaners and industrial cleaners. Depending on industries, there may be exposure to cadmium.

Conclusions

The current analysis is based on the six general population data sets from Belgium, France, Iceland, Israel, Lithuania, and Spain. The combined data set was divided into samples of potentially occupationally exposed subjects (relevant ISCO-08 codes with 4-digits) and to those who were not supposed to be occupationally exposed (non-relevant ISCO-08 codes). The third group was called "semi-relevant ISCO-08 codes" and included individuals who may work in occupations involving occupational exposure to target chemicals but the level of ISCO-08 coding (only 2 or 3 digits) did not allow to confirm it.

From the studied chemicals the results showed potential occupational exposure only to BPA, and to cadmium in the group of "Cleaners and helpers in offices, hotels and other establishments" (ISCO-08 code 9112). For BPA, most workers in the relevant ISCO-08 group were "Cashiers and Ticket Clerks", which is in accordance with the known exposure of these workers to BPA via thermal papers used in receipts. EU restriction of BPA in thermal paper (which came in force in January 2020) may not have yet impacted the exposure of this occupational group (sampling time between 2014—2021). It needs to be noted, however, that the number of samples in the relevant ISCO-08 group was rather low and therefore, the results should be interpreted with caution.

The reason for the higher urinary levels of cadmium among the group of "Cleaners and helpers in offices, hotels and other establishments" remains unclear, but it is noted that this group may include also industrial cleaners exposed to cadmium in industrial settings.

In this study, the number of study subjects for individual chemicals varied between 404—2946 (total number) and not all subjects were ISCO-08 encoded. Numbers of subjects especially in bisphenols (and hydroxybenzo[a]pyrene) groups were clearly too low to identify any other than very well-represented (common) occupational groups (like cashiers) and even in case of these occupational groups the number of subjects remained low (e.g. for BPA the number of relevant ISCO-08 code subjects was only 21). This reduces statistical power and increases the potential influence of other, confounding factors.

ISCO-08 codes with 2 or 3 digits are clearly too unspecific to make conclusions on occupational exposure. To identify potentially occupationally exposed groups in the general population data sets ISCO-08 encoding with at least 4 digits is needed. This requires that accurate information on occupation with detailed job description is collected via questionnaires or interviews. Without this information ISCO-08 coding with four or more digits is not possible. It is also recognized that coding with at least 4 digits is rather labor-intensive and requires expertise. For example, in this study, some data sets could not be included because of the limited resources of study owners to perform ISCO-08 coding. In addition, less detailed information on occupations collected in the surveys resulted in only 2 or 3-digit ISCO-coding, which were of limited use in this study. In future studies, more attention should be paid on the collection of information on occupations and job descriptions to allow sufficient ISCO coding for the analysis of the occupational exposures.

Smoking particularly affected the results for cadmium and 1-hydroxypyrenol. However, for these chemicals, occupational exposure could not be identified from the available data sets, even when smokers were excluded.

One aspect which may hamper the identification of occupational exposure from general population data sets is the sampling time, which is not specifically set for the identification of occupational exposure in general population cohorts. In occupational biomonitoring, the recommended sampling time in case of non-cumulative substances is usually after the work shift at the end of the working week. This typically captures the exposure during the past couple of working days. In the case of general population studies, the sampling time was first-morning-void or random spot

sample, and it was not possible to ensure whether the subjects had been working before the samplings (or had they been, e.g., on holidays). This may weaken the possible association with specific occupations.

In addition, attention should be paid also to the sampling year; regulatory and other risk management actions may affect the exposure of workers and the general population. This is the case for BPA, which was restricted in thermal papers in January 2020. Decreasing urinary levels of BPA have been observed in general population during the past ten years (Rodriguez Martin *et al.* 2023; Porras *et al.* 2024). The variable sampling years in the general population cohorts may confound the results in these cases.

Overall, it can be concluded — based on the datasets available in this study — that it is relatively difficult to identify occupationally exposed groups from the general population data. It is of utmost importance to have a high enough sample size, and ISCO-08 encoding with at least 4 digits to get meaningful results. This requires detailed data on occupations and job descriptions to be collected as part of general population surveys. What comes to the sample size, it is not possible to estimate the number of samples required for the study because it depends on the chemical, prevalence and magnitude of occupational exposure to that specific chemical in the population and on the representativeness of the study population. In some cases, the study population may be biased towards certain types of occupations (like cashiers, cleaners, office workers, etc.) whereas industrial workers showing higher exposure may be less represented. It is noted that this type of study design may better work with chemicals with low background biomarker levels and low background (environmentally caused) variation in biomarker levels. In this case, the results of occupationally exposed groups are likely to be more easily distinguishable from those of the general population if the prevalence of relevant occupations is sufficiently high in the population.

The results presented in this deliverable represent the preliminary analysis covering six general population studies. Analyses are planned to be completed with additional data set from Portugal and final results are communicated in a scientific article.

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Appendixes

Appendix 1 — Webropol Survey questions (first round)

Appendix 2 — Additional questionnaire (second round)

Appendix 3 — Tables of selected ISCO-08 codes for potential occupational exposure (i.e., relevant ISCO-08 codes)

Appendix 4 — The most common ISCO-08 codes in the data base

Appendix 5 — Number of urinary results for each relevant ISCO-08 code

Appendix 6 — Non-relevant ISCO-08 codes of which the urinary concentration exceeded the P95 value of the non-relevant ISCO-08 group

Appendix 7 — Effect on smoking on the urinary results of chromium and bisphenols

Appendix 1 – Webropol Survey questions (first round)

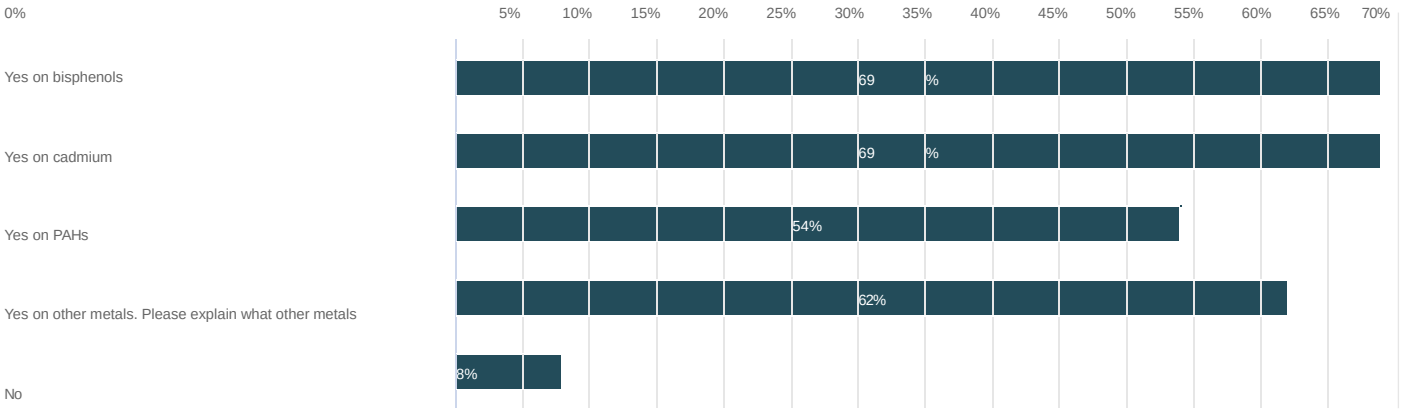
Basic report

PARC study on occupational information in general population surveys

Total number of respondents: 13

1. Does your study include HBM data on bisphenols, cadmium, or PAHs (or any other metals)?

Number of respondents: 13 , selected answers: 34



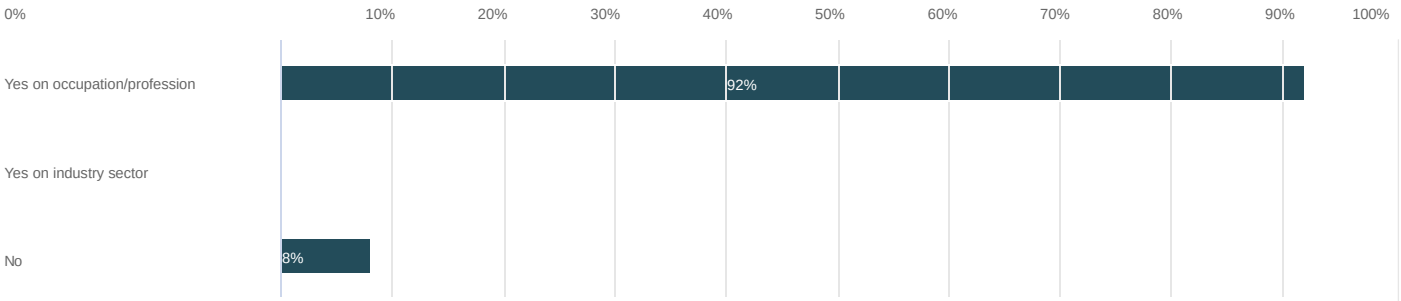
	n	Percent
Yes on bisphenols	9	69.2%
Yes on cadmium	9	69.2%
Yes on PAHs	7	53.8%
Yes on other metals. Please explain what other metals	8	61.5%
No	1	7.7%

Answers given into textfield
Show all

Option names	Text
Yes on other metals. Please explain what other metals	lead, mercury
Yes on other metals. Please explain what other metals	Pb, Hg, Cr, As, Zn
Yes on other metals. Please explain what other metals	As, B, Be, Bi, Pb, Cr, Co, Cu, Mn, Mo, Ni, Hg, In, Ag, Te, Tl, Zn, Sn, Sb, U, V
Yes on other metals. Please explain what other metals	Hg, Pb, AsT, Cr, Se, Cu, Zn
Yes on other metals. Please explain what other metals	lead, mercury (study period 2010-2012)
Yes on other metals. Please explain what other metals	lead, mercury, arsenic, chromium
Yes on other metals. Please explain what other metals	Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cesium, Chromium, Cobalt, Copper, Tin, Iridium, Lithium, Manganese, Mercury, Molybdenum, Nickel, Gold, Palladium, Platinum, Lead, Selenium, Thallium, Tungsten, Uranium, Valladium, Zinc
Yes on other metals. Please explain what other metals	Cobalt (urine) Mercury(Blood, urine, hair), Lead (urine, blood) Selenium (blood) Thallium (urine)

2. Is information on occupation/profession or industry requested?

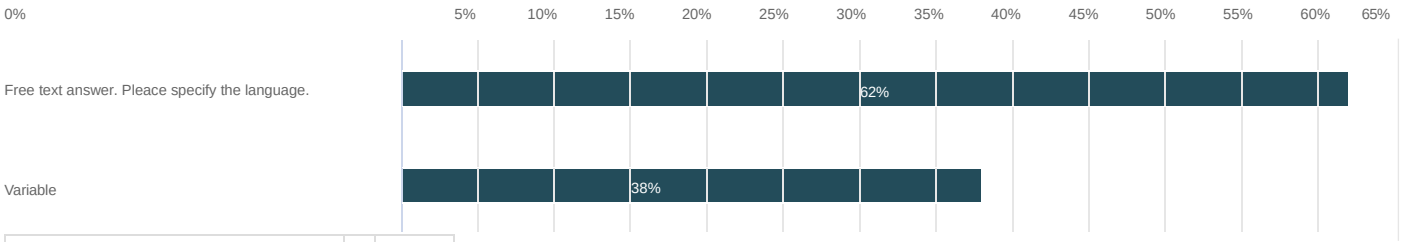
Number of respondents: 13



	n	Percent
Yes on occupation/profession	12	92.3%
Yes on industry sector	0	0.0%
No	1	7.7%

3. Is the answer on occupation/profession/industry given as free text or is it a variable?

Number of respondents: 13



	n	Percent
Free text answer. Please specify the language.	8	61.5%
Variable	5	38.5%

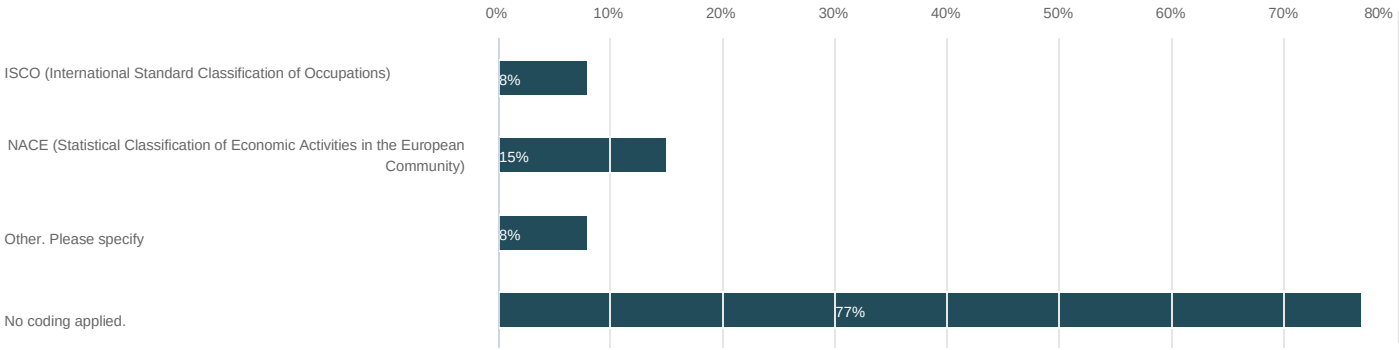
Answers given into textfield

Show all

Option names	Text
Free text answer. Please specify the language.	Finnish
Free text answer. Please specify the language.	Czech
Free text answer. Please specify the language.	Lithuanian
Free text answer. Please specify the language.	Croatian
Free text answer. Please specify the language.	German
Free text answer. Please specify the language.	french
Free text answer. Please specify the language.	Polish

4. What coding is applied?

Number of respondents: 13 , selected answers: 14



	n	Percent
ISCO (International Standard Classification of Occupations)	1	7.7%
NACE (Statistical Classification of Economic Activities in the European Community)	2	15.4%
Other. Please specify	1	7.7%
No coding applied.	10	76.9%

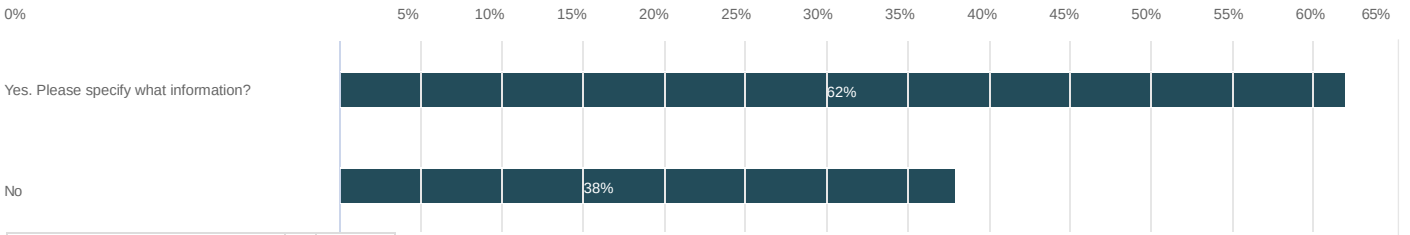
Answers given into textfield

Show all

Option names	Text
Other. Please specify	ISCED 2011

5. Does your study have any additional information on occupation?

Number of respondents: 13



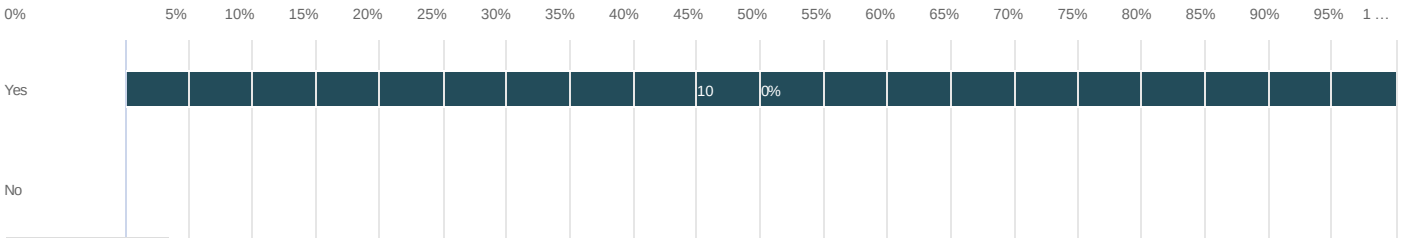
	n	Percent
Yes. Please specify what information?	8	61.5%
No	5	38.5%

Answers given into textfield
Show all

Option names	Text
Yes. Please specify what information?	the longest-held job: industry, position, duration
Yes. Please specify what information?	How long have you been in your current job? What are the last 3 jobs where you worked and for how long? Do you perform a systematic examination as part of your workplace and is biological monitoring (blood and urine) included? Did the previous work include systematic screening and biological monitoring? Do you have the technical conditions for safe work in the workplace?
Yes. Please specify what information?	We ask about the professional status; if last/curren occupation was in a leading position; in order to facilitate the classification of the current or last occupation, we ask the participant to enter additional explanations in keywords. Also we ask if the occupation is
Yes. Please specify what information?	substances into contact at work
Yes. Please specify what information?	information on working place (e.g. flooring)
Yes. Please specify what information?	Date of employement, Type of contract, Time spent at work, Size of company, Other occupational activity, Vacation in the last 12 months, sector of activity
Yes. Please specify what information?	Yes. "Is this your main job?" YES/NO
Yes. Please specify what information?	industry sector, possition, and others

6. Does your study include information on smoking status (smoker/non-smoker)?

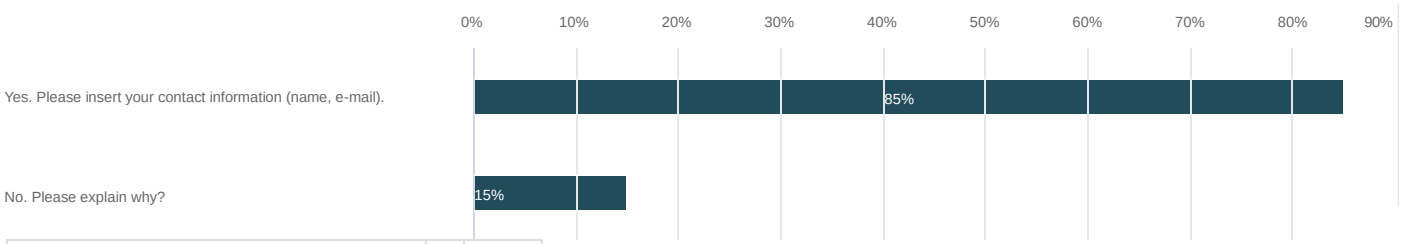
Number of respondents: 13



	n	Percent
Yes	13	100.0%
No	0	0.0%

7. Are you willing to collaborate and share your data for this study?

Number of respondents: 13



	n	Percent
Yes. Please insert your contact information (name, e-mail).	11	84.6%
No. Please explain why?	2	15.4%

Answers given into textfield
Show all

Option names	Text
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
Yes. Please insert your contact information (name, e-mail).	
No. Please explain why?	The data is from non-occupationally exposed population. None of the participants were occupationally exposed to BPA.
No. Please explain why?	The study population is aged 24 y and the majority is studying, Thus, there will be few participants in each occupational group. Moreover, coding of the information on occupation is currently not planned and we do not have resources to perform this work currently.

Appendix 2 — Additional questionnaire (second round)

Dear … / Study Owner,

Thank you for your interest to share your research data within the Partnership for the Assessment of Risk of Chemicals (PARC) Feasibility study to evaluate occupational exposure in general population surveys. The result of the survey is about 10 potentially interesting research data sets. Next step is that we need to decide what studies and chemicals we will focus on. In order to do that we need to ask couple of additional questions.

But before that please, confirm that you are still interested to share your data within this study?

Additional question:	**Answer:**
What is the sample collection year?	
What is the study population?	
Size of the population?	
Country / area of sample collection?	
Is the data published? If yes, please give the reference.	
If the information on occupation/profession is given as variable, can you please explain what does it mean?	
Is the study data included in the HBM4EU Dashboard?	
Have you applied HBM4EU code book type of coding to your data?	
In what format your data could be shared (Excel, SPSS, R, etc.)?	

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Are you available to co-operate with the data mining, possible language translation or further coding of your data?	

Data owner of all studies finally included in this PARC Feasibility study are invited as co-authors of the study report and possible scientific papers (max. 2 persons/data owner).

We will arrange a meeting regarding all those studies suitable to be included in the PARC Feasibility study. This is likely to take place in March.

Would you please answer to this message no later than 6th of February, 2023. Thank you in advance!

Best greetings,

Simo Porras & Tiina Santonen

Finnish Institute of Occupational Health, Helsinki, Finland

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Appendix 3 — Tables of selected ISCO-08 codes (i.e., relevant ISCO-08 codes)

Table 1. Occupations for a potential cadmium exposure.

ISCO-08	Occupations
0110	Commissioned armed forces officers
0210	Non-commissioned armed forces officers
1219	Business services and administration managers not elsewhere classified
1223	Research and development managers
1311	Agricultural and forestry production managers
1321	Manufacturing managers
2113	Chemists
2131	Biologists, botanists, zoologists and related professionals
2133	Environmental protection professionals
2141	Industrial and production engineers
2142	Civil engineers
2143	Environmental engineers
2144	Mechanical engineers
2146	Mining engineers, metallurgists and related professionals
2149	Engineering professionals not elsewhere classified
2151	Electrical engineers
2164	Town and traffic planners
2263	Environmental and occupational health and hygiene professionals
2651	Visual artists
3112	Civil engineering technicians
3113	Electrical engineering technicians
3115	Mechanical engineering technicians
3117	Mining and metallurgical technicians
3119	Physical and engineering science technicians not elsewhere classified
3121	Mining supervisors
3122	Manufacturing supervisors
3123	Construction supervisors
3131	Power production plant operators
3132	Incinerator and water treatment plant operators
3135	Metal production process controllers
3139	Process control technicians not elsewhere classified
3141	Life science technicians (excluding medical)
3153	Aircraft pilots and related associate professionals

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3221	Nursing associate professionals
3257	Environmental and occupational health inspectors and associates
3322	Commercial sales representatives
3431	Photographers
4321	Stock clerks
5153	Building caretakers
6111	Field Crop and Vegetable Growers
6112	Tree and Shrub Crop Growers
6113	Gardeners; Horticultural and Nursery Growers
6114	Mixed Crop Growers
6310	Subsistence crop farmers
6320	Subsistence cattle farmer
6330	Mixed subsistence farmer
7111	House builders
7119	Building frame and related trades workers not elsewhere classified
7121	Roofers (Installers of metal roofing)
7123	Plasterers
7124	Insulation workers
7126	Plumbers and Pipe Fitters (Installers of metal drains, gutters and ducts)
7127	Air conditioning and refrigeration mechanics
7131	Painters and related workers
7132	Spray painters and varnishers
7132	Spray painters and varnishers
7211	Metal Moulders and Coremakers
7212	Welders & Flame Cutters
7213	Sheet Metal Workers
7214	Structural Metal Preparers and Erectors
7215	Riggers and Cable Splicers
7223	Metal working machine tool setters and operators
7224	Metal polishers, wheel grinders and tool sharpeners
7231	Motor vehicle mechanics and repairers
7232	Aircraft engine mechanics and repairers
7233	Agricultural and industrial machinery mechanics and repairers
7311	Precision-instrument Makers and Repairers
7312	Musical Instrument Makers and Tuners
7313	Jewellery and Precious metal Workers
7314	Potters and Related Workers
7315	Glass Makers, Cutters, Grinders and Finishers
7316	Signwriters, Decorative Painters, Engravers and Etchers

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7317	Handicraft Workers in Wood, Basketry and Related Materials
7318	Handicraft Workers in Textile, Leather and Related Materials
7319	Handicraft Workers Not Elsewhere Classified
7412	Electrical mechanics and fitters
7421	Electronics mechanics and servicers
7544	Fumigators and Other Pest and Weed Controllers
8111	Miners and quarriers
8112	Mineral and stone processing plant operators
8113	Well drillers and borers and related workers
8121	Metal processing plant operators
8122	Metal Finishing, Plating and Coating Machine Operators:
8131	Chemical Products Plant and Machine Operators.
8154	Bleaching, Dyeing And Fabric Cleaning Machine Operators
8181	Glass and Ceramics Plant Operators
8189	Stationary plant and machine operators not elsewhere classified
8212	Electrical and Electronic Equipment Assemblers
8332	Heavy truck and lorry drivers
8342	Earthmoving and related plant operators
8343	Crane, hoist and related plant operators
8344	Lifting truck operators
8344	Lifting truck operators
9112	Cleaners and helpers in offices, hotels and other establishments
9211	Crop farm labourers
9212	Livestock farm labourers
9213	Mixed crop and livestock farm labourers
9311	Mining and quarrying labourers
9612	Refuse Sorters
9624	Water and firewood collectors

Table 2. Occupations for a potential chromium exposure.

ISCO-08	**Occupations**
0110	Commissioned armed forces officers
131	Production managers in agriculture, forestry and fisheries
0210	Non-commissioned armed forces officers
0310	Armed forces occupations, other ranks
1120	Managing directors and chief executives
1211	Finance managers
1221	Sales and marketing managers

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1321	Manufacturing managers
2113	Chemists
2132	Farming, forestry and fisheries advisers
2133	Environmental protection professionals
2141	Industrial and production engineers
2142	Civil engineers
2143	Environmental engineers
2144	Mechanical engineers
2146	Mining Engineers, Metallurgists and Related Professionals
2149	Engineering Professionals Not Elsewhere Classified
2151	Electrical Engineers
2152	Electronics Engineers
2153	Telecommunications engineers
2164	Town and traffic planners
2310	University and higher education teachers
2320	Vocational education teachers
2330	Secondary education teachers
2355	Other arts teachers
2411	Accountants
2431	Advertising and marketing professionals
2634	Psychologists
3111	Chemical and physical science technicians
3113	Electrical engineering technicians
3115	Mechanical engineering technicians
3117	Mining and metallurgical technicians
3119	Physical and engineering science technicians not elsewhere classified
3121	Mining supervisors
3122	Manufacturing supervisors
3123	Construction supervisors
3131	Power production plant operators
3132	Incinerator and water treatment plant operators
3133	Agricultural and industrial machinery mechanics and repairers
3134	Petroleum and natural gas refining plant operators
3135	Metal production process controllers
3141	Life science technicians (excluding medical)
3212	Medical and pathology laboratory technicians
3322	Commercial sales representatives
3355	Police inspectors and detectives
3412	Social work associate professionals

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3431	Photographers
4321	Stock clerks
5153	Building caretakers
6113	Gardeners, horticultural and nursery growers
7111	House builders
7112	Bricklayers and related workers
7113	Stonemasons, stone cutters, splitters and carvers
7114	Concrete placers, concrete finishers and related workers
7119	Building frame and related trades workers not elsewhere classified
7122	Floor layers and tile setters
7123	Plasterers
7124	Insulation workers
7126	Plumbers and pipe fitters
7127	Air conditioning and refrigeration mechanics
7131	Painters and Related Workers
7132	Spray Painters and Varnishers
7133	Building Structure Cleaners
7211	Metal moulders and coremakers
7212	Welders & Flame Cutters:
7213	Sheet-metal workers
7214	Structural-metal preparers and erectors
7221	Blacksmiths, hammersmiths and forging press workers
7222	Toolmakers and related workers
7223	Metal working machine tool setters and operators
7224	Metal polishers, wheel grinders and tool sharpeners
7231	Motor vehicle mechanics and repairers
7232	Aircraft engine mechanics and repairers
7233	Agricultural and industrial machinery mechanics and repairers
7311	Precision-instrument makers and repairers
7316	Signwriters, Decorative Painters, Engravers and Etchers
7318	Handicraft workers in textile, leather and related materials
7321	Pre-press technicians
7322	Printers
7411	Building and related electricians
7412	Electrical mechanics and fitters
7421	Electronics mechanics and servicers
7521	Wood treaters
7522	Cabinet-makers and related workers
7534	Upholsterers and related workers

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7535	Pelt Dressers, Tanners and Fellmongers
7536	Shoemakers and related workers
8111	Miners and quarriers
8112	Mineral and stone processing plant operators
8113	Well drillers and borers and related workers
8114	Cement, stone and other mineral products machine operators
8121	Metal processing plant operators
8122	Metal Finishing, Plating and Coating Machine Operators
8131	Chemical Products Plant and Machine Operators
8132	Photographic Products Machine Operators
8142	Plastic products machine operators
8154	Bleaching, Dyeing and Fabric Cleaning Machine Operators
8155	Fur and Leather Preparing Machine Operators
8156	Shoemaking and Related Machine Operators
8157	Laundry machine operator
8159	Textile, Fur and Leather Products Machine Operators Not Elsewhere Classified
8171	Pulp and papermaking plant operators
8181	Glass and ceramics plant operators
8211	Mechanical Machinery Assemblers
8212	Electrical and Electronic Equipment Assemblers
8219	Assemblers not elsewhere classified
8332	Heavy truck and lorry drivers
8341	Mobile farm and forestry plant operators
8342	Earthmoving and related plant operators
9112	Cleaners and helpers in offices, hotels and other establishments
9121	Hand launderers and pressers
9129	Other cleaning workers
9311	Mining and quarrying labourers
9313	Building construction labourers
9321	Hand packers
9333	Freight handlers
9612	Refuse Sorters

Table 3. Occupations for a potential bisphenol exposure.

ISCO-08	**Occupations**
2145	Chemical engineers
3214	Medical and Dental Prosthetic Technicians

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4221	Travel consultants and clerks
5211	Stall and Market salespersons
5212	Street food salespersons
5221	Shopkeepers
5222	Shop supervisors
5223	Shop sales assistants
5230	Cashiers and Ticket Clerks
5245	Service station attendants
5246	Food service counter attendants
5329	Personal care workers in health services not elsewhere classified
7212	Plastic welders
7311	Precision-instrument makers and repairers
8142	Plastic Products Machine Operators
8171	Pulp and papermaking plant operators
9520	Street vendors (excluding food)
9611	Garbage and recycling collectors
9612	Refuse Sorters

Table 4. Occupations for a potential PAH exposure.

ISCO-08	**Occupations**
0110	Commissioned armed forces officers
0210	Non-commissioned armed forces officers
0310	Armed forces occupations, other ranks
1219	Business services and administration managers not elsewhere classified
1321	Manufacturing managers
1323	Construction managers
1349	Professional services managers not elsewhere classified
2113	Chemists
2131	Biologists, botanists, zoologists and related professionals
2133	Environmental protection professionals
2141	Industrial and production engineers
2142	Civil engineers
2143	Environmental engineers
2144	Mechanical engineers
2145	Chemical engineers
2149	Engineering professionals not elsewhere classified
2151	Electrical engineers
2152	Electronics engineers
2164	Town and traffic planners

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2263	Environmental and occupational health and hygiene professionals
2320	Vocational education teachers
2424	Training and staff development professionals
3113	Electrical engineering technicians
3115	Mechanical engineering technicians
3116	Chemical engineering technicians
3119	Physical and engineering science technicians not elsewhere classified
3121	Mining supervisors
3122	Manufacturing supervisors
3123	Construction supervisors
3131	Power production plant operators
3132	Incinerator and water treatment plant operators
3139	Process control technicians not elsewhere classified
3141	Life science technicians (excluding medical)
3152	Ships' deck officers and pilots
3212	Medical and pathology laboratory technicians
3257	Environmental and occupational health inspectors and associates
3258	Ambulance workers
3315	Valuers and loss assessors
3322	Commercial sales representatives
3355	Police inspectors and detectives
3411	Police inspectors and detectives
3431	Photographers
4321	Stock clerks
5153	Building caretakers
5245	Service Station Attendants
5411	Firefighters
5412	Police officers
7111	House builders
7112	Bricklayers and related workers
7113	Stonemasons, stone cutters, splitters and carvers
7115	Carpenters and joiners
7119	Building frame and related trades workers not elsewhere classified
7121	Roofers
7122	Floor layers and tile setters
7123	Plasterers
7124	Insulation workers
7126	Plumbers and pipe fitters
7127	Air conditioning and refrigeration mechanics
7133	Building Structure Cleaners

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7211	Metal Moulders and Coremakers
7212	Welders and flamecutters
7214	Structural-metal preparers and erectors
7223	Metal working machine tool setters and operators
7231	Motor vehicle mechanics and repairers
7233	Agricultural and industrial machinery mechanics and repairers
7311	Precision-instrument makers and repairers
7316	Sign writers, decorative painters, engravers and etchers
7411	Building and related electricians
7412	Electrical mechanics and fitters
7413	Electrical line installers and repairers
7421	Electronics mechanics and servicers
7422	Information and communications technology installers and servicers
7521	Wood treaters
7522	Cabinet-makers and Related Workers
7542	Shotfirers and blasters
8111	Mining and Mineral Processing Plant Operators
8112	Mineral and Stone Processing Plant Operators
8113	Well Drillers and Borers and Related Workers
8114	Cement, Stone and Other Mineral Products Machine Operators
8121	Metal processing plant operators
8122	Metal Finishing, Plating and Coating Machine Operators
8141	Rubber products machine operators
8142	Plastic products machine operators
8181	Glass and ceramics plant operators
8182	Steam engine and boiler operators
8219	Assemblers not elsewhere classified
8312	Railway brake, signal and switch operators
8332	Heavy truck and lorry drivers
8342	Earthmoving and Related Plant Operators
8343	Crane, hoist and related plant operators
8344	Lifting truck operators
9112	Cleaners and helpers in offices, hotels and other establishments
9129	Other cleaning workers
9311	Mining and quarrying labourers
9312	Civil engineering labourers
9313	Building construction labourers
9333	Freight handlers
9612	Refuse sorters

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Appendix 4 — The most common ISCO-08 codes in the data base

Table 1. The most common ISCO-08 codes in the database ordered by number of hits (N).

ISCO-08	N	Occupations
4110	268	General Office Clerks
5419	90	Protective Services Workers Not Elsewhere Classified
9112	78	Cleaners and Helpers in Offices, Hotels and Other Establishments
2221	59	Nursing Professionals
7231	55	Motor Vehicle Mechanics and Repairers
9633	45	Sweepers and related labourers
2211	42	Generalist Medical Practitioners
3322	39	Commercial Sales Representatives
7113	38	Stonemasons, Stone Cutters, Splitters and Carvers
23	37	Teaching Professionals
9333	34	Freight Handlers
5321	34	Health Care Assistants
2133	33	Environmental Protection Professionals
7411	31	Building and Related Electricians
5120	30	Cooks
7123	29	Plasterers
9329	28	Manufacturing Labourers Not Elsewhere Classified
5311	26	Child Care Workers
5230	26	Cashiers and Ticket Clerks
2330	26	Secondary Education Teachers
21	26	Science and Engineering Professionals
1420	26	Retail and Wholesale Trade Managers
751	24	Food Processing and Related Trades Workers
1349	24	Professional Services Managers Not Elsewhere Classified
1120	24	Managing Directors and Chief Executives
3353	23	Government Social Benefits Officials
1219	22	Business Services and Administration Managers Not Elsewhere Classified
7119	20	Building Frame and Related Trades Workers Not Elsewhere Classified
5223	20	Shop Sales Assistants
8219	19	Assemblers Not Elsewhere Classified
8160	19	Food and Related Products Machine Operators
6113	19	Gardeners, Horticultural and Nursery Growers
9313	18	Building Construction Labourers

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7126	18	Plumbers and Pipe Fitters
5221	17	Shopkeepers
4419	17	Clerical Support Workers Not Elsewhere Classified
25	17	Information and Communications Technology Professionals
214	17	Engineering Professionals (excluding Electrotechnology)
9211	16	Crop Farm Labourers
7131	16	Painters and Related Workers
4226	16	Receptionists (general)
2341	16	Primary School Teachers
8189	15	Stationary Plant and Machine Operators Not Elsewhere Classified
5131	14	Waiters
4120	14	Secretaries (general)
3141	14	Life Science Technicians (excluding Medical)
432	13	Material Recording and Transport Clerks
41	13	General and Keyboard Clerks
3123	13	Construction Supervisors
24	13	Business and Administration Professionals

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Appendix 5 — Number of urinary results for each relevant ISCO-08 code

Table 1. Number of urinary results (N) for each relevant ISCO-08 code (arranged by ISCO-08 code).

Cadmium		
ISCO-08	**N**	**Occupations**
1219	22	Business Services and Administration Managers Not Elsewhere Classified
1311	1	Agricultural and Forestry Production Managers
2113	11	Chemists
2131	10	Biologists, Botanists, Zoologists and Related Professionals
2133	33	Environmental Protection Professionals
2141	3	Industrial and Production Engineers
2142	3	Civil Engineers
2143	2	Environmental Engineers
2144	3	Mechanical Engineers
2149	4	Engineering Professionals Not Elsewhere Classified
2151	6	Electrical Engineers
2164	1	Town and Traffic Planners
2263	2	Environmental and Occupational Health and Hygiene Professionals
3112	5	Civil Engineering Technicians
3115	1	Mechanical Engineering Technicians
3122	1	Manufacturing Supervisors
3123	13	Construction Supervisors
3131	4	Power Production Plant Operators
3132	2	Incinerator and Water Treatment Plant Operators
3139	5	Process Control Technicians Not Elsewhere Classified
3141	14	Life Science Technicians (excluding Medical)
3221	1	Nursing Associate Professionals
3322	39	Commercial Sales Representatives
4321	3	Stock Clerks
5153	5	Building Caretakers
6112	1	Tree and Shrub Crop Growers
6113	19	Gardeners, Horticultural and Nursery Growers
6114	8	Mixed Crop Growers
6320	1	Subsistence Livestock Farmers
6330	1	Subsistence Mixed Crop and Livestock Farmers
7111	4	House Builders
7119	20	Building Frame and Related Trades Workers Not Elsewhere Classified
7121	1	Roofers
7123	29	Plasterers

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7126	18	Plumbers and Pipe Fitters
7127	3	Air Conditioning and Refrigeration Mechanics
7131	16	Painters and Related Workers
7211	3	Metal Moulders and Coremakers
7212	10	Welders and Flame Cutters
7213	2	Sheet Metal Workers
7214	4	Structural Metal Preparers and Erectors
7223	12	Metal Working Machine Tool Setters and Operators
7231	55	Motor Vehicle Mechanics and Repairers
7232	1	Aircraft Engine Mechanics and Repairers
7233	1	Agricultural and Industrial Machinery Mechanics and Repairers
7313	1	Jewellery and Precious Metal Workers
7421	12	Electronics Mechanics and Servicers
8111	5	Miners and Quarriers
8121	1	Metal Processing Plant Operators
8122	8	Metal Finishing, Plating and Coating Machine Operators
8131	12	Chemical Products Plant and Machine Operators
8189	15	Stationary Plant and Machine Operators Not Elsewhere Classified
8332	13	Heavy Truck and Lorry Drivers
8342	4	Earthmoving and Related Plant Operators
8343	2	Crane, hoist and related plant operators
8344	2	Lifting Truck Operators
9112	77	Cleaners and Helpers in Offices, Hotels and Other Establishments
9211	16	Crop Farm Labourers
9212	1	Livestock Farm Labourers
9612	3	Refuse Sorters
Chromium		
ISCO-08	**N**	**Occupations**
1120	1	Managing Directors and Chief Executives
2132	1	Farming, Forestry and Fisheries Advisers
2133	31	Environmental Protection Professionals
2141	1	Industrial and Production Engineers
2142	3	Civil Engineers
2143	2	Environmental Engineers
2152	1	Electronics Engineers
2310	2	University and Higher Education Teachers
2330	24	Secondary Education Teachers
2411	4	Accountants
2431	1	Advertising and Marketing Professionals

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2634	3	Psychologists
3111	3	Chemical and Physical Science Technicians
3117	1	Mining and metallurgical technicians
3122	1	Manufacturing Supervisors
3123	2	Construction Supervisors
3141	7	Life Science Technicians (excluding Medical)
3212	2	Medical and Pathology Laboratory Technicians
3322	3	Commercial Sales Representatives
3355	2	Police Inspectors and Detectives
3412	4	Social Work Associate Professionals
6113	1	Gardeners, Horticultural and Nursery Growers
7112	2	Bricklayers and Related Workers
7126	4	Plumbers and Pipe Fitters
7131	1	Painters and Related Workers
7213	1	Sheet Metal Workers
7231	2	Motor Vehicle Mechanics and Repairers
7232	1	Aircraft Engine Mechanics and Repairers
7322	1	Printers
8131	2	Chemical Products Plant and Machine Operators
8211	1	Mechanical Machinery Assemblers
8219	2	Assemblers Not Elsewhere Classified
8342	1	Earthmoving and Related Plant Operators
9112	5	Cleaners and Helpers in Offices, Hotels and Other Establishments
9321	2	Hand Packers
9333	6	Freight Handlers
Bisphenols		
ISCO-08	**N**	**Occupations**
2145	1	Chemical Engineers
5222	2	Shop Supervisors
5223	3	Shop Sales Assistants
5230	15	Cashiers and Ticket Clerks
Pyrene		
ISCO-08	**N**	**Occupations**
1219	2	Business Services and Administration Managers Not Elsewhere Classified
1323	1	Construction Managers
1349	4	Professional Services Managers Not Elsewhere Classified
2113	1	Chemists
2131	3	Biologists, Botanists, Zoologists and Related Professionals

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2133	32	Environmental Protection Professionals
2141	1	Industrial and Production Engineers
2142	3	Civil Engineers
2143	2	Environmental Engineers
2144	2	Mechanical Engineers
2145	2	Chemical Engineers
2149	2	Engineering Professionals Not Elsewhere Classified
2151	5	Electrical Engineers
2152	2	Electronics Engineers
2320	1	Vocational Education Teachers
3123	7	Construction Supervisors
3131	2	Power Production Plant Operators
3132	2	Incinerator and Water Treatment Plant Operators
3139	1	Process Control Technicians Not Elsewhere Classified
3141	12	Life Science Technicians (excluding Medical)
3212	1	Medical and Pathology Laboratory Technicians
3322	21	Commercial Sales Representatives
3355	1	Police Inspectors and Detectives
4321	1	Stock Clerks
5153	3	Building Caretakers
5411	2	Fire Fighters
5412	1	Police Officers
7111	1	House Builders
7113	25	Stonemasons, Stone Cutters, Splitters and Carvers
7115	6	Carpenters and Joiners
7119	13	Building Frame and Related Trades Workers Not Elsewhere Classified
7123	14	Plasterers
7126	6	Plumbers and Pipe Fitters
7127	1	Air Conditioning and Refrigeration Mechanics
7211	2	Metal Moulders and Coremakers
7212	5	Welders and Flame Cutters
7214	3	Structural Metal Preparers and Erectors
7223	5	Metal Working Machine Tool Setters and Operators
7231	22	Motor Vehicle Mechanics and Repairers
7233	1	Agricultural and Industrial Machinery Mechanics and Repairers
7411	25	Building and Related Electricians
7421	8	Electronics Mechanics and Servicers
7522	1	Cabinet-makers and Related Workers
8111	3	Miners and Quarriers
8122	6	Metal Finishing, Plating and Coating Machine Operators

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8141	2	Rubber Products Machine Operators
8219	13	Assemblers Not Elsewhere Classified
8332	5	Heavy Truck and Lorry Drivers
8342	3	Earthmoving and Related Plant Operators
8343	1	Crane, hoist and related plant operators
9112	23	Cleaners and Helpers in Offices, Hotels and Other Establishments
9313	9	Building Construction Labourers
9333	19	Freight Handlers
Benzo[a]pyrene		
ISCO-08	**N**	**Occupations**
2131	1	Biologists, Botanists, Zoologists and Related Professionals
2141	1	Industrial and Production Engineers
2151	5	Electrical Engineers
3322	2	Commercial Sales Representatives
3355	1	Police Inspectors and Detectives
5411	2	Fire Fighters
5412	1	Police Officers
7111	1	House Builders
7115	1	Carpenters and Joiners
7126	1	Plumbers and Pipe Fitters
7211	2	Metal Moulders and Coremakers
7231	2	Motor Vehicle Mechanics and Repairers
8219	2	Assemblers Not Elsewhere Classified
8343	1	Crane, hoist and related plant operators
9112	1	Cleaners and Helpers in Offices, Hotels and Other Establishments
9333	2	Freight Handlers

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Appendix 6 — Non-relevant ISCO-08 codes of which the urinary concentration exceeded the P95 value of the non-relevant ISCO-08 group

Table 1. Non-relevant ISCO-08 codes of which the urinary concentration exceeded the P95 value of the non-relevant group. N>1 means that the same ISCO-08 code had multiple exceeding results.

Cadmium		
ISCO-08	**N**	**Occupations**
111	1	Legislators and Senior Officials
1330	1	Information and Communications Technology Service Managers
1349	1	Professional Services Managers Not Elsewhere Classified
1420	2	Retail and Wholesale Trade Managers
2114	1	Geologists and geophysicists
2211	4	Generalist Medical Practitioners
2221	3	Nursing Professionals
2222	1	Midwifery Professionals
2269	2	Health Professionals Not Elsewhere Classified
23	3	Teaching Professionals
2330	1	Secondary Education Teachers
2341	1	Primary School Teachers
2413	1	Financial Analysts
2432	2	Public Relations Professionals
25	2	Information and Communications Technology Professionals
2511	1	Systems Analysts
261	1	Legal Professionals
2631	1	Economists
2633	1	Philosophers, Historians and Political Scientists
2634	1	Psychologists
2643	1	Translators, Interpreters and Other Linguists
2652	2	Musicians, Singers and Composers
3111	1	Chemical and Physical Science Technicians
3256	1	Medical Assistants
334	1	Administrative and Specialized Secretaries
3344	1	Medical Secretaries
3355	1	Police Inspectors and Detectives
341	1	Legal, Social and Religious Associate Professionals
3412	1	Social Work Associate Professionals
351	1	Information and Communications Technology Operations and User Support Technicians
41	2	General and Keyboard Clerks
4110	3	General Office Clerks

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4226	1	Receptionists (general)
4419	1	Clerical Support Workers Not Elsewhere Classified
5120	3	Cooks
5222	1	Shop Supervisors
5223	3	Shop Sales Assistants
5230	1	Cashiers and Ticket Clerks
5242	1	Sales Demonstrators
5246	1	Food Service Counter Attendants
5311	1	Child Care Workers
5321	1	Health Care Assistants
5322	2	Home-based Personal Care Workers
5412	1	Police Officers
5419	2	Protective Services Workers Not Elsewhere Classified
7112	1	Bricklayers and Related Workers
7113	3	Stonemasons, Stone Cutters, Splitters and Carvers
7411	1	Building and Related Electricians
751	2	Food Processing and Related Trades Workers
753	1	Garment and Related Trades Workers
8159	2	Textile, Fur and Leather Products Machine Operators Not Elsewhere Classified
8219	2	Assemblers Not Elsewhere Classified
8322	1	Car, Taxi and Van Drivers
9215	2	Forestry Labourers
9329	1	Manufacturing Labourers Not Elsewhere Classified
9333	1	Freight Handlers
9334	1	Shelf Fillers
941	1	Food Preparation Assistants
9629	2	Elementary Workers Not Elsewhere Classified
9633	1	Sweepers and related labourers
Chromium		
ISCO-08	**N**	**Occupations**
2221	1	Nursing Professionals
2341	1	Primary School Teachers
242	1	Administration Professionals
261	1	Legal Professionals
3118	1	Draughts persons
3256	1	Medical Assistants
3334	1	Real Estate Agents and Property Managers
334	2	Administrative and Specialized Secretaries
3344	1	Medical Secretaries

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351	1	Information and Communications Technology Operations and User Support Technicians
41	1	General and Keyboard Clerks
5223	1	Shop Sales Assistants
5230	1	Cashiers and Ticket Clerks
5311	1	Child Care Workers
5321	1	Health Care Assistants
5322	1	Home-based Personal Care Workers
7422	1	Information and Communications Technology Installers and Servicers
7511	1	Butchers, Fishmongers and Related Food Preparers
921	1	Agricultural, Forestry and Fishery Labourers
BPA		
ISCO-08	**N**	**Occupations**
2133	1	Environmental Protection Professionals
2141	1	Industrial and Production Engineers
2221	1	Nursing Professionals
2269	1	Health Professionals Not Elsewhere Classified
23	4	Teaching Professionals
2341	1	Primary School Teachers
25	1	Information and Communications Technology Professionals
3211	1	Medical Imaging and Therapeutic Equipment Technicians
3256	1	Medical Assistants
334	1	Administrative and Specialized Secretaries
3342	1	Legal Secretaries
3353	1	Government Social Benefits Officials
341	1	Legal, Social and Religious Associate Professionals
41	1	General and Keyboard Clerks
5411	1	Fire Fighters
7112	1	Bricklayers and Related Workers
7422	1	Information and Communications Technology Installers and Servicers
BPF		
ISCO-08	**N**	**Occupations**
2133	1	Environmental Protection Professionals
2151	1	Electrical Engineers
2221	1	Nursing Professionals
2269	1	Health Professionals Not Elsewhere Classified
2341	1	Primary School Teachers
2352	2	Special Needs Teachers
2633	1	Philosophers, Historians and Political Scientists

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2634	1	Psychologists
3123	1	Construction Supervisors
3256	1	Medical Assistants
3333	1	Employment agents and contractors
3334	1	Real Estate Agents and Property Managers
334	1	Administrative and Specialized Secretaries
3353	1	Government Social Benefits Officials
351	1	Information and Communications Technology Operations and User Support Technicians
41	1	General and Keyboard Clerks
4223	1	Telephone Switchboard Operators
8342	1	Earthmoving and Related Plant Operators
BPS		
ISCO-08	**N**	**Occupations**
1112	1	Senior Government Officials
213	1	Life Science Professionals
2133	2	Environmental Protection Professionals
2141	1	Industrial and Production Engineers
2143	1	Environmental Engineers
2152	1	Electronics Engineers
2221	1	Nursing Professionals
23	1	Teaching Professionals
2330	1	Secondary Education Teachers
25	1	Information and Communications Technology Professionals
2512	1	Software Developers
3353	2	Government Social Benefits Officials
41	1	General and Keyboard Clerks
51	1	Personal Service Workers
5321	1	Health Care Assistants
8131	1	Chemical Products Plant and Machine Operators
8322	1	Car, Taxi and Van Drivers
Pyrene		
ISCO-08	**N**	**Occupations**
1330	1	Information and Communications Technology Service Managers
1344	1	Social Welfare Managers
2211	1	Generalist Medical Practitioners
2221	1	Nursing Professionals
2330	1	Secondary Education Teachers
25	1	Information and Communications Technology Professionals

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2619	1	Legal Professionals Not Elsewhere Classified
2631	1	Economists
2652	1	Musicians, Singers and Composers
3111	1	Chemical and Physical Science Technicians
3353	2	Government Social Benefits Officials
351	1	Information and Communications Technology Operations and User Support Technicians
41	2	General and Keyboard Clerks
4110	7	General Office Clerks
4120	1	Secretaries (general)
4222	1	Contact Centre Information Clerks
4416	1	Personnel Clerks
4419	1	Clerical Support Workers Not Elsewhere Classified
5120	1	Cooks
5131	1	Waiters
522	1	Shop Salespersons
5221	1	Shopkeepers
5223	1	Shop Sales Assistants
5230	1	Cashiers and Ticket Clerks
5419	2	Protective Services Workers Not Elsewhere Classified
6113	1	Gardeners, Horticultural and Nursery Growers
7131	1	Painters and Related Workers
751	4	Food Processing and Related Trades Workers
8159	1	Textile, Fur and Leather Products Machine Operators Not Elsewhere Classified
8189	1	Stationary Plant and Machine Operators Not Elsewhere Classified
8311	1	Locomotive Engine Drivers
9329	1	Manufacturing Labourers Not Elsewhere Classified

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Appendix 7 — Effect on smoking on the urinary results of chromium and bisphenols

Descriptive statistics

Table 1. Descriptive statistics of urinary chromium regarding all results, the results of smokers, and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	636	0.160	0.374	0.778	1.369	2.007	12.226
Relevant ISCO-08	131	0.047	0.040	0.400	0.792	1.004	5.272
Semi-relevant ISCO-08	119	0.606	0.606	1.022	1.755	2.238	5.993
Non-relevant ISCO-08	386	0.161	0.375	0.792	1.396	2.140	12.226
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	167	0.225	0.442	0.778	1.233	1.607	5.993
Relevant ISCO-08	42	0.138	0.289	0.527	0.881	0.937	5.272
Semi-relevant ISCO-08	22	0.517	0.658	0.914	1.105	1.125	5.993
Non-relevant ISCO-08	103	0.231	0.442	0.816	1.381	1.654	4.814
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	467	0.143	0.363	0.784	1.450	2.083	12.226
Relevant ISCO-08	89	0.029	0.016	0.171	0.732	0.999	2.088
Semi-relevant ISCO-08	96	0.629	0.602	1.080	1.820	2.329	4.078
Non-relevant ISCO-08	282	0.143	0.359	0.781	1.400	2.155	12.226

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

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Table 2. Descriptive statistics of urinary BPA regarding all results, the results of smokers, and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	425	1.181	1.289	2.535	5.169	9.274	91.716
Relevant ISCO-08	21	1.635	1.825	2.764	3.212	3.270	5.336
Semi-relevant ISCO-08	16	1.945	2.231	2.636	4.886	7.030	9.418
Non-relevant ISCO-08	388	1.137	1.232	2.478	5.274	9.418	91.716
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	93	1.620	1.953	3.826	7.429	10.876	71.121
Relevant ISCO-08	3	2.959	2.661	3.999	4.801	5.069	5.336
Semi-relevant ISCO-08	3	3.759	2.389	5.904	8.012	8.715	9.418
Non-relevant ISCO-08	87	1.541	1.748	3.722	7.330	11.568	71.121
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	330	1.072	1.123	2.301	4.524	7.824	91.716
Relevant ISCO-08	18	1.481	1.473	2.704	3.022	3.221	3.270
Semi-relevant ISCO-08	13	1.670	1.331	2.549	3.410	4.616	6.234
Non-relevant ISCO-08	299	1.032	1.059	2.226	4.627	8.585	91.716

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Table 3. Descriptive statistics of urinary BPF regarding all results, the results of smokers, and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	402	0.137	0.182	0.382	0.847	1.067	9.624
Relevant ISCO-08	21	0.141	0.235	0.698	1.337	1.371	2.576
Semi-relevant ISCO-08	11	0.276	0.281	0.420	0.500	1.073	1.646

Non-relevant ISCO-08	370	0.134	0.178	0.368	0.816	1.030	9.624
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	86	0.237	0.255	0.485	0.957	1.650	9.624
Relevant ISCO-08	3	0.247	0.328	1.452	2.127	2.352	2.576
Semi-relevant ISCO-08	0	NA	NA	NA	NA	NA	NA
Non-relevant ISCO-08	83	0.237	0.255	0.471	0.917	1.117	9.624
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	314	0.118	0.150	0.362	0.811	1.039	8.057
Relevant ISCO-08	18	0.128	0.231	0.658	1.282	1.342	1.371
Semi-relevant ISCO-08	11	0.276	0.281	0.420	0.500	1.073	1.646
Non-relevant ISCO-08	285	0.113	0.144	0.334	0.716	1.021	8.057

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Table 4. Descriptive statistics of urinary BPS regarding all results, the results of smokers, and non-smokers. Results are given in unit of µg/g creatinine.

All results							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	402	0.196	0.220	0.578	1.575	2.618	324.981
Relevant ISCO-08	21	0.057	0.162	0.273	0.885	1.243	1.557
Semi-relevant ISCO-08	11	0.302	0.300	0.347	0.637	4.948	9.259
Non-relevant ISCO-08	370	0.208	0.221	0.590	1.803	2.690	324.981
Smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	86	0.279	0.252	0.532	2.253	4.337	21.042
Relevant ISCO-08	3	0.087	0.172	0.376	0.498	0.539	0.580
Semi-relevant ISCO-08	0	NA	NA	NA	NA	NA	NA

Non-relevant ISCO-08	83	0.292	0.253	0.530	2.427	4.628	21.042
Non-smokers							
Group	**N**	**GM**	**Median**	**P75**	**P90**	**P95**	**Max**
All observations	314	0.179	0.199	0.625	1.544	2.503	324.981
Relevant ISCO-08	18	0.053	0.147	0.270	0.992	1.290	1.557
Semi-relevant ISCO-08	11	0.302	0.300	0.347	0.637	4.948	9.259
Non-relevant ISCO-08	285	0.190	0.197	0.641	1.559	2.545	324.981

GM, geometric mean; P75, 75th percentile; P90, 90th percentile; P95, 95th percentile.

Statistical comparisons

Table 5. Statistical comparison of urinary chromium results of smokers and non-smokers. One-tailed test results are shown.

		Mann—Whitney		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=42)	Relevant ISCO-08, non-smokers (N=89)	0.305	**<0.001**	**<0.001**
Semi-relevant ISCO-08, smokers (N=22)	Semi-relevant ISCO-08, non-smokers (N=96)	0.533	0.684	0.689
Non-relevant ISCO-08, smokers (N=103)	Non-relevant ISCO-08, non-smokers (N=282)	0.452	0.073	0.065
Relevant ISCO-08, smokers (N=42)	Non-relevant ISCO-08, smokers (N=103)	0.393	0.978	0.981
Relevant ISCO-08, smokers (N=42)	Semi-relevant ISCO-08, smokers (N=22)	0.255	0.999	1.000
Semi-relevant ISCO-08, smokers (N=22)	Non-relevant ISCO-08, smokers (N=103)	0.616	**0.045**	**0.029**
Relevant ISCO-08, non-smokers (N=89)	Non-relevant ISCO-08, non-smokers (N=282)	0.307	1.000	1.000
Relevant ISCO-08, non-smokers (N=89)	Semi-relevant ISCO-08, non-smokers (N=96)	0.127	1.000	1.000
Semi-relevant ISCO-08, non-smokers (N=96)	Non-relevant ISCO-08, non-smokers (N=282)	0.678	**<0.001**	**<0.001**

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Table 6. Statistical comparison of urinary BPA results of smokers and non-smokers. One-tailed test results are shown.

		Mann—Whitney		Brunner—Munzel
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=3)	Relevant ISCO-08, non-smokers (N=18)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=3)	Semi-relevant ISCO-08, non-smokers (N=13)	-[a]	-[a]	-[a]
Non-relevant ISCO-08, smokers (N=87)	Non-relevant ISCO-08, non-smokers (N=299)	0,394	**0,001**	**0,002**
Relevant ISCO-08, smokers (N=3)	Non-relevant ISCO-08, smokers (N=87)	-[a]	-[a]	-[a]
Relevant ISCO-08, smokers (N=3)	Semi-relevant ISCO-08, smokers (N=3)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=3)	Non-relevant ISCO-08, smokers (N=87)	-[a]	-[a]	-[a]
Relevant ISCO-08, non-smokers (N=18)	Non-relevant ISCO-08, non-smokers (N=299)	0.617	**0.047**	**0.022**
Relevant ISCO-08, non-smokers (N=18)	Semi-relevant ISCO-08, non-smokers (N=13)	0.509	0.476	0.470
Semi-relevant ISCO-08, non-smokers (N=13)	Non-relevant ISCO-08, non-smokers (N=299)	0.633	0.052	**0.020**

[a] Not enough samples to make a statistical comparison.

Table 7. Statistical comparison of urinary BPF results of smokers and non-smokers. One-tailed test results are shown.

		Mann—Whitney		Brunner—Munzel
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=3)	Relevant ISCO-08, non-smokers (N=18)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=0)	Semi-relevant ISCO-08, non-smokers (N=11)	-[a]	-[a]	-[a]
Non-relevant ISCO-08, smokers (N=83)	Non-relevant ISCO-08, non-smokers (N=285)	0,364	**<0,001**	**<0,001**
Relevant ISCO-08, smokers (N=3)	Non-relevant ISCO-08, smokers (N=83)	-[a]	-[a]	-[a]
Relevant ISCO-08, smokers (N=3)	Semi-relevant ISCO-08, smokers (N=0)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=0)	Non-relevant ISCO-08, smokers (N=83)	-[a]	-[a]	-[a]

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Relevant ISCO-08, non-smokers (N=18)	Non-relevant ISCO-08, non-smokers (N=285)	0.545	0.262	0.306
Relevant ISCO-08, non-smokers (N=18)	Semi-relevant ISCO-08, non-smokers (N=11)	0.434	0.725	0.721
Semi-relevant ISCO-08, non-smokers (N=11)	Non-relevant ISCO-08, non-smokers (N=285)	0.667	**0.030**	**0.007**

[a] Not enough samples to make a statistical comparison.

Table 8. Statistical comparison of urinary BPS results of smokers and non-smokers. One-tailed test results are shown.

		Mann—Whitney		**Brunner—Munzel**
Group 1	**Group 2**	**Effect size**	**P-value**	**P-value**
Relevant ISCO-08, smokers (N=3)	Relevant ISCO-08, non-smokers (N=18)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=0)	Semi-relevant ISCO-08, non-smokers (N=11)	-[a]	-[a]	-[a]
Non-relevant ISCO-08, smokers (N=83)	Non-relevant ISCO-08, non-smokers (N=285)	0.431	**0.029**	**0.022**
Relevant ISCO-08, smokers (N=3)	Non-relevant ISCO-08, smokers (N=83)	-[a]	-[a]	-[a]
Relevant ISCO-08, smokers (N=3)	Semi-relevant ISCO-08, smokers (N=0)	-[a]	-[a]	-[a]
Semi-relevant ISCO-08, smokers (N=0)	Non-relevant ISCO-08, smokers (N=83)	-[a]	-[a]	-[a]
Relevant ISCO-08, non-smokers (N=18)	Non-relevant ISCO-08, non-smokers (N=285)	0.384	0.951	0.920
Relevant ISCO-08, non-smokers (N=18)	Semi-relevant ISCO-08, non-smokers (N=11)	0.338	0.927	0.935
Semi-relevant ISCO-08, non-smokers (N=11)	Non-relevant ISCO-08, non-smokers (N=285)	0.562	0.242	0.176

[a] Not enough samples to make a statistical comparison.

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