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Human bio-monitoring study around a plant that recycles and refines precious metals in Central Italy

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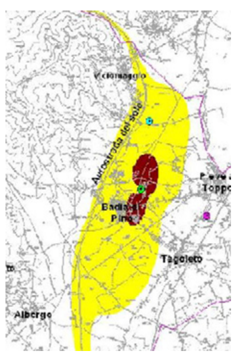
HIGHLIGHTS

- We compared urinary biomarkers of residents in the study area, in an urban area and in a control area.
- High urinary levels of Hg, Ag and Ni in the study and in the urban area suggested common environmental pressures.
- Data on dispersion of plant emissions together with data from human bio-monitoring are useful for public heath purposes.

GRAPHICAL ABSTRACT



Information on environmental exposure of subjects living in the neighbourhood of a plant are obtained comparing results of the urinary biomonitoring of these subjects with those concerning dispersion of the plant emissions obtained through a diffusional model as well as comparing them with those obtained in a reference population and in a population living in an urban area.

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ABSTRACT

In an area characterized by the presence of a plant that recycles and refines precious metals the study aims to evaluate the exposure to the plant emissions of the residents in the neighbourhood using human urinary biomarkers, in comparison with those obtained in a reference and in an urban area and with the data concerning dispersions of plant emissions obtained through a specific diffusional model. 153 subjects in the study area, 95 in the urban area and 55 in the reference area, aged 18–60 years, answered to a self-administered questionnaire and collected their 24-h urine. Urinary concentrations of antimony, silver, cadmium, cobalt, chromium, mercury, nickel, platinum, creatinine, and the porphyrin patterns were detected. The results for the 3 areas were compared using parametric and non-parametric tests. Significant higher concentrations of mercury, cadmium, silver and nickel are observed in the study area in comparison with the reference area, but no differential distribution was observed by different levels of environmental pollution defined by the study's diffusion model, and no correlation was found between the concentrations of altered urinary porphyrin and metals. Life styles being equal, residents in the study area as well as residents in the urban area have high urinary levels of mercury, silver and nickel in comparison with the reference area, suggesting common environmental pressures probably related to diffuse gold processing activities, suggesting common environmental pressures. The excess of cadmium only in the study area suggests a role played by exposure to plant emissions, even if a differential distribution was not observed by different levels of environmental pollution.

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1. Introduction

A plant that recycles and refines precious metals, also using incineration methods, has been active since the mid '70s in a small municipality located in the Eastern part of Tuscany. In addition, 20 years later the plant began to burn hospital waste. Residents in the neighbourhood as well as local public administrations have expressed great apprehension over the possible health impact of exposures to plant emissions, especially when mercury (Hg) and dioxins and then furans exceeded the threshold limit values, in 2005 and in 2006 respectively, and when, more recently, the plant asked to double its industrial activity.

A human bio-monitoring pilot study was carried out during 2008–2009 in order to define the most efficient biological markers of human exposure to plant emissions in urine and blood (Chellini et al., 2015). The pilot study showed higher concentrations of antimony (Sb), cadmium (Cd), and nickel (Ni) in urinary samples of male residents in the area of interest in comparison with residents in a reference area. The residents nearby the plant also showed a high percentage of altered urinary porphyrin patterns.

The design of the study presented in this paper includes several suggestions from the pilot study: to verify environmental exposure of the living population in the study area using only urine matrix, to enlarge the study population to include women, to take into consideration not only a reference area but also an area characterized by another type of anthropic pollution (specifically an area characterized by traffic pollution), and finally to compare the urinary porphyrin patterns of subjects living in the study area with those obtained in subjects living in the other two areas.

The aims of this study are to evaluate the exposure to plant emissions of the adult population resident in the neighbourhood using human urinary biomarkers, comparing the results both with those obtained in a reference and in an urban area and with the data concerning dispersions of plant emissions obtained through a specific diffusional model.

2. Methods

2.1. Study population

It is a geographical cross sectional human bio-monitoring study, carried out during 2011–2013. Residents in three areas of the province of Arezzo were invited to participate in the study: the first area is characterized by the presence of a plant that incinerates waste materials (the study area), the second one is the urban area of Arezzo (the urban area), very close to the study area and characterized by traffic pollution beyond diffuse small gold processing activities, and the third is a small municipality located on the closest mountain characterized by tourism and forestry activities (the reference area). All participants had to fulfill the following selection criteria in order not to present major characteristics that could be related to the outcome of the studies: being a resident in each area for at least ten years; being aged 18–60 years at time of enrolment; being willing to collect their 24-h urine and to answer to a self-administered questionnaire; not being affected by kidney failure, hereditary porphyria or thalassemic trait; not being drug, alcohol or vitamin supplement consumers; being non-smokers or ex-smokers since at least 5 years; and not having an occupational history in gold- and metal-working or in garbage collecting and incineration activities.

The number of subjects to include in the study was estimated considering the pilot study results and was comprised of 180 subjects in the study area, 150 in the urban area and 100 in the reference area. The number of subjects in the study area was defined a priori to be more than those of the reference area in order to be able to make comparisons of observed metal concentrations by different levels of pollution defined by the dispersion model in the study area. The number of subjects to be necessary to highlight a significant difference between the study area and the reference area was estimated taking into consideration the results on differences observed in the pilot study (Chellini et al., 2015): assuming 90% power of the study and an 0.05 α error the subjects in each area had to be 86, 25 and 36 to obtain significant differences for Sb, Cd, and Ni urinary concentrations respectively.

The general practitioners (GPs) operating in the three areas cooperated in the enrolment of the participants, selecting those fulfilling the selection criteria from their patient files or, in the case of self-selection, confirming their health status and behavioural characteristics necessary to allow them to take part in the study. A letter explaining the aim and the procedure of the study was sent to all subjects identified by GPs in order to obtain their informed participation. Posters on the ongoing study were hung up in the GPs' practices and in public places of the three areas.

The protocol of the study was approved by the Ethical Committee of the Local Health Administration of Arezzo (Provv. D.A. no. 1068/2010).

2.2. Urine and life style data collection

Each participant received a plastic sunlight-shaded container and instructions on how to collect 24-h urine. Trained health personnel contacted the participants, gave them the urine containers and recovered the containers when they were full. Then they measured the total urine 24-h volume collected by each participant. 100 milliliters of each individual's collected urine was poured in a test tube, upon which only the subject identification number was written, frozen at −18 °C, and brought to the Public Health Laboratory for chemical analyses. Both types of container were previously cleaned using nitric acid at 5% by the same laboratory.

All participants had to complete a specific questionnaire to register information on personal characteristics, occupational activities, hobbies, drug use, presence of amalgam tooth filling, and exposures to passive smoking and traffic pollutants. These information were useful in the statistical analysis in order to exclude the impact of exposures to other risk factors that could be related to urinary metal concentrations.

2.3. Laboratory analysis

Although more urinary metals could have been analyzed, these analyzed in this study were identified in the pilot study for their specific relevance to the study area: Cd because it is a good marker of previous exposures to combustion processes and the best marker of plant emissions; Ni, Co, Ag and Sb because they are used in alloys; Hg because a specific emission from the plant exceeding the limit value was registered 6 years before; Pt because it is a good marker of traffic pollution as well as plant emissions; and Cr, while very common in nature, because it can be also emitted in the air by combustion processes. The Public Health Laboratory of Siena, in particular two of the authors (CA and GS), performed the chemical analysis of the collected urine samples without knowing the samples' origin areas. Concentrations of Sb, silver (Ag), Cd, cobalt (Co), chromium (Cr), mercury (Hg), Ni, platinum (Pt), creatinine, and the porphyrin patterns were detected in the collected 24-h urine samples of all participants. The validity of the laboratory analytical methods was assured by fulfilling standard and referral procedures (Table 1).

2.4. Statistical analysis

Statistical analysis on the urinary metal concentration was performed using the logarithmic converted value of each metal concentration. The normal distributions of the logarithmic converted values were checked using the Gauss test (skewness and kurtosis test of normality). The Shapiro-Wilk W test and the Shapiro-Francia W test were used in the case of normality rejection. The number of outliers was identified with the Grubbs test. The range of values (minimum and maximum), the median and its 95% confidence intervals (95% CI), the standard deviation (SD), and the geometric mean (GM) with its 95% CI were calculated for each metal. If the values lower than the limit of quantification