



Pattern of blood concentrations of 47 elements in two populations from the same geographical area but with different geological origin and lifestyles: Canary Islands (Spain) vs. Morocco

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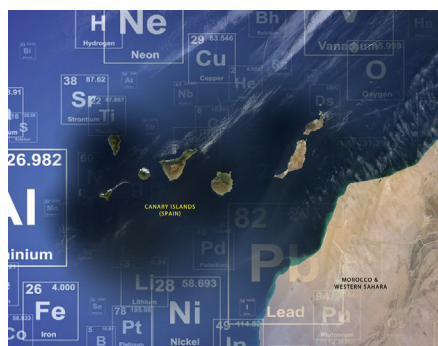
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HIGHLIGHTS

- Worryingly high levels of Pb in the young males of Morocco (<40% above safe threshold)
- Higher levels of Zn, Se, As, Cd, and the sum of hi-tech-related elements in Moroccans
- Higher levels of Mn, Nb, and Bi in Canarians
- Geographical vicinity of both territories is not a major determinant of each other's pollution.

GRAPHICAL ABSTRACT



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ABSTRACT

The Canary Islands are one of the outermost regions of the European Union (EU), which are located barely 100 km from the coasts of Morocco. Although these islands are located in Africa, the degree of socioeconomic development and lifestyle in this archipelago is comparable to that of any other region of Europe. It is well established that the main determinants of human exposure to elements have to do both, with their place of residence and with habits related to their lifestyle. For this reason, we wanted to study the pattern of contamination by elements of these two populations so geographically close, but so different both in their lifestyle, and the geological origin of the territory where they live. Thus, we have determined the blood concentrations of 47 elements (including 25 rare earth elements (REE) and other minority elements (ME) widely employed in the hi-tech industry) in a paired sample of Moroccans ($n = 124$) and Canary Islands inhabitants ($n = 120$). We found that the levels of iron, selenium, zinc, arsenic, cadmium, strontium, and specially lead, were significantly higher in Moroccans than in Canarians, probably due to the intensive mining activity in this country. We also found significantly higher levels of the sum of REE and ME in Moroccans than in Canarians, possibly related to the inappropriate management of e-waste in this country. On the other hand, in the inhabitants of the Canary Islands we

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found higher levels of manganese, probably related to a higher degree of exposure to heavy traffic and exposure to Saharan dust of the people living in this region, and niobium and bismuth, probably related to the higher economic development in these islands. Our results indicate that the vicinity of both territories is not a major determinant of each other's contamination.

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1. Introduction

Human exposure to environmental concentrations of elements has become in many cases a cause for concern, even when referring to those trace elements that are essential for life (Tchounwou et al., 2012). In fact, a total of 23 elements are included in the Agency for Toxic Substances and Disease Registry (ATSDR) priority pollutants list (CDC, 2017). Additionally, living beings are being increasingly exposed to a group of elements that could be considered as “emerging pollutants”. These are mainly the rare earth elements (REE) and other minor elements (ME) that are highly coveted due to their peculiar properties (electronic configuration), which make them very useful (or almost indispensable) for the manufacturing of all kinds of today's technological devices (Tansel, 2017). Because their enormous range of applications, these elements are being mobilized from the few sites where they are abundant to be employed at an industrial scale, and therefore distributed all over the planet (Bozlaker et al., 2013). The whole range of toxicological effects of many of these elements are unknown to date, but based on the few available evidences, the REEs and some other MEs have been included among the emerging occupational and environmental health risks by several international organizations (Pagano et al., 2015).

In recent years several studies have focused in studying the environmental contamination by elements in developing countries, especially in those where the mining activities are very relevant, but also in those where the informal processing of electronic waste (e-waste) is increasing (Henríquez-Hernández et al., 2017a; Henríquez-Hernández et al., 2017b; Hussain and Mumtaz, 2014; Laissaoui and Rochat, 2008; Manhart et al., 2011; Nnorom and Osibanjo, 2008; Xu et al., 2015; Zeng et al., 2016). A recent study in non-occupationally exposed African populations, indicated that the highest levels of contamination by certain elements, such as As or Pb, were exhibited by Moroccan participants ($n = 18$) (Henríquez-Hernández et al., 2017b). This was one of the reasons why we designed the present research, aimed to studying the apparently high exposure to certain elements of the inhabitants of Morocco and Western Sahara in more depth.

The Canary Islands (Spain) belong to the group of regions called “outermost regions of the European Union”, since they are geographically located far away from the European continent. In this case, these islands are located barely 100 km from the coasts of Morocco in the Atlantic Ocean (see Graphical Abstract). However, this region is comparable to any other in the European Union, both from the sociocultural point of view and from economic development, and it occupies position 175 of the 276 regions of the EU (EUROSTAT, 2017). This level of development, together with proximity to Africa, has made this archipelago an attraction pole for irregular immigration from developing countries of Africa, in search of an opportunity to improve their standard of living. Thus, in the last two decades it is estimated that >150,000 immigrants from >25 countries across the African continent have arrived in the Canary Islands (Rodríguez et al., 2008). The participation of researchers from our group in the assessment of the general health status of these immigrants at the time of their arrival, has given us the unique opportunity to study in depth many aspects of the health of the African general population, obtaining numerous data and conclusions that otherwise would have been very difficult to obtain (de-la-Iglesia-Inigo et al., 2013; Henríquez-Hernández et al., 2017a; Henríquez-Hernández et al., 2016a; Henríquez-Hernández et al., 2016b; Luzardo et al., 2014; Perez-Arellano and Carranza-Rodríguez, 2016; Sanz-Peláez et al.,

2008; Ternavasio-de-la-Vega et al., 2009). One of the interests of our research group has been to identify the sources of contamination of the Canary population, as well as to compare their levels of contamination to that of the neighboring populations (Bas et al., 2012; Boada et al., 2007; Boada et al., 2012; Henríquez-Hernández et al., 2011; Henríquez-Hernández et al., 2017c; Henríquez-Hernández et al., 2017d; Luzardo et al., 2006; Luzardo et al., 2009; Luzardo et al., 2013; Zumbado et al., 2005; Zumbado et al., 2010).

In this context, we performed this human biomonitoring study, in which we determined the blood concentrations of 47 elements, including essential trace elements, classic toxic elements, and elements related to the technology industry, with a triple objective: i) to assess for the first time the level of contamination by these elements of the general population of the Canary Islands; ii) to provide, also for the first time, data of many of these elements in a representative sample of a part of the general population of Morocco (mainly young adult males); and finally iii) to compare the levels of contamination by these elements between both populations in order to disclose how their geographical proximity could influence to each other.

2. Material and methods

2.1. Study population

The study population consisted on 124 Moroccan immigrants recently arrived to the Canary Islands (25.9 ± 5.9 years old), and 120 permanent inhabitants of this archipelago (29.9 ± 6.2 years old). The characteristics of these two population samples are detailed in Table 1. The Moroccans were sequentially and prospectively recruited within the first two months after their arrival on the island of Gran Canaria. It is mandatory that all the irregular immigrants coming from Africa are subjected to a face-to-face interview, and have complete health exam while they were temporarily lodged in government shelters to screen them for the detection of imported diseases. As a part of this screening, blood samples are obtained from them within 10 days after upon arrival in the Canary Islands to complete different analyses (immunological, hematological, biochemical, parasitological, and nutritional parameters). An aliquot of this blood sample from each participant was employed for the analysis of elements. An informed consent was obtained from each one of the participants, as approved by the Ethics Committee of both institutions (CHUIMI and ULPGC) (de-la-Iglesia-Inigo et al., 2013). The samples belonging to permanent inhabitants of the Canary Islands were obtained from the Spanish Red Cross blood bank during the same period of immigrants' recruitment, after they were

Table 1
Characteristics of participants in the study.

	Moroccan	Canarian
Total samples	124 (100%)	120 (100%)
Gender ^a		
Male	116 (95.1%)	56 (46.7%)
Female	6 (4.9%)	64 (53.3%)
Age (years)		
Mean \pm SD	25.9 \pm 5.9	29.9 \pm 6.2
Median	25	30
Range	15–55	20–40

Number and percentage were included, except for continuous variables, which were described as mean \pm standard deviation (SD), median and global range.

^a Missed data in 2 subjects belonging to the Maghreb group.

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