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Study of the influencing factors of the blood levels of toxic elements in Africans from 16 countries☆

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ABSTRACT

Africa's economy is growing faster than any other continent and it has been estimated that the middle class in Africa now exceeds 350 million people. This has meant a parallel increase in the importation of consumer goods and in the implementation of communication and information technologies (ICT), but also in the generation of large quantities of e-waste. However, inadequate infrastructure development remains a major constraint to the continent's economic growth and these highly toxic residues are not always adequately managed. Few studies have been conducted to date assessing the possible association between socioeconomic development factors, including e-waste generation, and blood levels of inorganic elements in African population. To disclose the role of geographical, anthropogenic, and socioeconomic development determinants on the blood levels of Ag, Al, As, Be, Cd, Co, Cr, Hg, Ni, Pb, Sb, and V —all of them frequently found in e-waste—, an immigrant population-based study was made including a total of 245 subjects from 16 countries recently arrived to the Canary Islands (Spain). Women presented higher levels of blood elements than men, and Northern Africans (Moroccans) were the most contaminated. People from low-income countries exhibited significantly lower blood levels of inorganic elements than those from middle-income countries. We found a significant association between the use of motor vehicles and the implementation of information and communication technologies (ICT) and the level of contamination. Immigrants from the countries with a high volume of imports of second-hand electronic equipment, telephone and internet use had higher levels of inorganic elements. In general terms, the higher level of economic development the higher the blood levels of inorganic pollutants, suggesting that the economic development of Africa, in parallel to e-waste generation and the existence of informal recycling sites, have directly affected the level of contamination of the population of the continent.

1. Introduction

It is well established that the presence of pollutants in body fluids shows the individual's actual systemic exposure to a chemical agent from all potential routes of exposure. Thus, human biomonitoring (HBM) is an acknowledged tool for measurement chemical exposure (Angerer et al., 2007). Several countries, especially developed countries from Europe and North America, undertake national HBM programs (Angerer et al., 2006) on a regular basis, or at least have run the determination of certain pollutants in general population or specific subpopulation groups by means of independent studies (Porta et al., 2010, 2012; Zumbado et al.,

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2005). However, in many developing countries, including the majority of African nations, virtually no HBM studies have been performed, and therefore there is a lack of information on the background levels of environmental pollutants in the general population. However, despite the limitations given by the economic, logistic, and idiosyncratic characteristics of African countries, some few data have been reported referred to persistent organic pollutants (POPs) in specific population subgroups of certain countries (Asante et al., 2011; Ejobi et al., 1996; Henriquez-Hernandez et al., 2016; Pieters and Focant, 2014), or in the general population by means of studies carried out on newly arrived immigrants to European countries, that allow a simultaneous study of a sample of the general population from a good number of countries (Luzardo et al., 2014). Regarding to inorganic pollutants, the available data are even more scarce, and in addition to some studies published in certain subpopulations (i.e. children) of a few African countries (Khlifi et al., 2014; Laamech et al., 2014; Moawad et al., 2016; Tuakuila et al., 2015), little is known of the levels of heavy metals and other metalloids in the general African population.

Unlike POPs or other organic contaminant, heavy metals and elements have been used by humans for thousands of years, and therefore human populations have been exposed to their known adverse effects since then (Jarup, 2003). However, it has been reported that human exposure to heavy metals has been steadily increasing in some parts of the world, and especially in less developed countries (EPA, 2007; Jarup, 2003) as a consequence of the massive use of these elements in industrial processes and high tech products. Continuous exposure to low levels of these toxic trace elements may result in bioaccumulation and cause a wide variety of adverse biological effects on human beings (depending upon the level and duration of exposure) (Mortada et al., 2002). The most sensitive targets for the toxic effect of inorganic compounds are the nervous system (both central and peripheral), the hematological and cardiovascular systems, the respiratory system, and the kidney (Bas et al., 2012; Koyashiki et al., 2010; Zeng et al., 2016). Children are especially vulnerable to the toxic effects of these chemicals (Jarup, 2003). Since for many elements (i.e. Hg, As, or Pb) the margin between the level of exposure and adverse effects is small, it is imperative the initiation of HBM studies of the general population, especially in areas of high exposure such as many African countries (Garrison et al., 2014; Gioia et al., 2014; Linderholm et al., 2010). The situation may be even more dramatic in those countries where regulation and policies regarding the environmental levels of inorganic compounds are lacking, which constitutes a major public health problem (Fewtrell et al., 2003).

Electronic waste (e-waste) refers to end-of-life electronic products, including computers, mobile phones, washing machines, air conditioners, television sets, and others, which are composed of sophisticated blends of plastics and metals, among other materials. E-waste has been reported as a relevant source of organic and inorganic environmental pollutants (Hussain and Mumtaz, 2014), constituting one of the most discussed global environmental issues. Unfortunately, Africa has experienced an illegal trade of e-waste from developed countries and it is estimated that up to 80% of e-waste generated in developed countries is exported to developing countries (UNEP, 2011). Moreover, in an attempt to bridge the "digital divide", many African countries are importing increasing amounts of second-hand electric and electronic equipment (EEE) from developed countries. These devices have a considerably shorter useful life, and quickly become unusable, which turns into an increase of e-waste generation. The problem is that the importing countries lack the necessary infrastructure for an environmentally sound management of e-waste (UNEP, 2011). Apart from inorganic contaminants, organic pollutants are derived from e-waste recycling processes (Xu et al., 2015), and it has been recently reported that the economic development of Africa and the e-waste generation have directly affected the levels of POPs of its population (Luzardo et al., 2014).

In this setting, the initiation of HBM studies of the general population of Africa is recommended. However, the economic, logistic, and idiosyncratic characteristics of African countries make this assessment a challenge. For this reason, immigrant population-based studies can be used to obtain information that would otherwise be very difficult to obtain. The Canary Islands are a territory of the European Union (Spain) in Africa (100 km off the coast of Morocco), that has been a frequent target of irregular immigration from African countries. Thus, from 1999 to 2011, over 100,000 immigrants from the African continent are estimated to have arrived by sea to the Canary coast (Rodríguez et al., 2008). Our research group has been involved in the health assessment of these immigrants on their arrival to the Canary Islands, and this has given us the exceptional opportunity of recruiting a cohort of Africans from different countries, which can be considered a representation of a part the general population (age range 15–49 y.o.) of a big part of the continent. This is the reason why we developed this immigrant population-based study, with the aim of obtaining a glimpse of the baseline levels of inorganic pollution of the inhabitants of an extensive region of the African continent. We focused on contaminants that are usually related to e-waste, because we wanted to test the hypothesis that the current levels of these contaminants are affected by the degree of socioeconomic development, and the corresponding increase in e-waste generation. To our knowledge, no previous studies have been conducted to assess levels of inorganic pollutants in migrants from Africa.

2. Material and methods

2.1. Study population

The study population consisted of 245 African immigrants from 16 African countries. We sequentially and prospectively recruited the volunteers within the first two months after their arrival on the island of Gran Canaria (Canary Islands, Spain). As previously reported, we recruited people who were temporarily lodged in shelters as part of the general screening for imported diseases (Luzardo et al., 2014). All of the participants provided their written consent for the use of their biological samples for research. They underwent a physical examination to rule out the presence of signs or symptoms of disease. We conducted a supplementary face-to-face interview in English or French following a pre-established questionnaire (de-la-Iglesia-Inigo et al., 2013; Sanz-Pelaez et al., 2008). Trained nurses recorded their heights and weights, and their corresponding body mass index (BMI) was calculated. Height was measured to the nearest 1 cm, and weight was measured to the nearest 0.1 kg. Blood samples were obtained from all of the participants. First, blood samples were analyzed to determine immunological, hematological, biochemical, parasitological, and nutritional parameters. The remaining blood was kept frozen at −80 °C until the element analysis was performed. The demographic characteristics of the participants and the variables in this study are presented in Table 2, and the economic development indicators of their countries of origin for the period 2006–2010 are presented in Supplementary Table 1 (The-World-Bank, 2006; The-World-Bank, 2013).

2.2. Standards, samples and elements

We measured the blood levels of 12 elements frequently detected in electronic gadgets and e-waste (Hussain and Mumtaz, 2014; Tansel, 2017): Ag (atomic mass 107), Al (27), As (75), Be (9),