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Different pattern of contamination by legacy POPs in two populations from the same geographical area but with completely different lifestyles: Canary Islands (Spain) vs. Morocco

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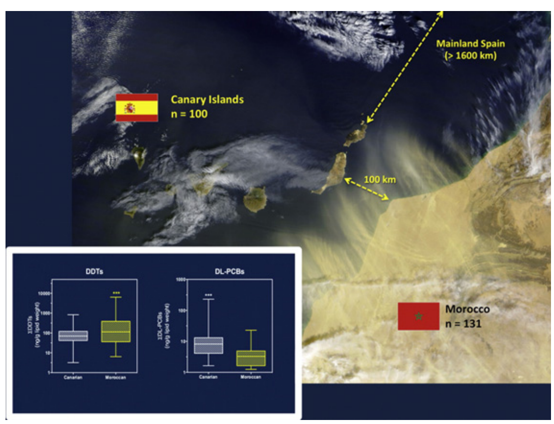
HIGHLIGHTS

- First report of plasma levels of OCPs and PCBs in Moroccan population
- OCPs were higher among Moroccan than Canarian population (Spain).
- Dioxin-like PCBs were higher among Canarian than Moroccan population.
- Geographical vicinity does not seem to be a major determinant of serum levels of POPs.

GRAPHICAL ABSTRACT



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ABSTRACT

The archipelago of the Canary Islands is one of the so-called ultra-peripheral territories of the European Union due to its geographical location away from the continent. Although the level of socioeconomic development and lifestyle of this region is comparable to that of any other of the European Union, it is just 100 km off the coast of Morocco, in the African continent. The population of the Canaries has been extensively studied with respect to their levels of POPs, and it has been described that their levels are relatively high compared to other European regions. It has been speculated with that the proximity to Africa may be associated with this level of contamination, but so far this theory has not been verified. This paper describes for the first time the levels of organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in a sample of the population of Morocco ($n = 131$), which were compared with those of a similar sample of the population of permanent residents in the Canary Islands ($n = 100$) in order to check this hypothesis. Our results showed that Moroccans have higher median values of OCPs than the residents in the Canaries ($\sum$ OCP = 150.2 ng/g lw vs. 83.4 ng/g lw, $p = 0.0001$).

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Morocco
Canary Islands
Lifestyle

Regarding the PCBs, although recent studies have reported that new environmental sources of PCBs exist in several African countries (including Morocco), the plasma levels of most congeners were significantly higher in Canarians than in Moroccans, especially for the dioxin-like PCBs (median = 7.3 ng/g lw vs. 0.0 ng/g lw, p = 0.0001). The detailed analysis of our results suggests that the levels of these pollutants in the Canarian people are more influenced by their lifestyle and the previous use of these chemicals in the archipelago than by its geographical vicinity with Morocco.

1. Introduction

Persistent organic pollutants (POPs) are a group of anthropogenic chemicals of concern due to their widely proved association with an increased risk of many human diseases (Casals-Casas and Desvergne, 2011; Henriquez-Hernandez et al., 2014; Hernández et al., 2015; Lee et al., 2014). The chemicals within this group are resistant to biotic and abiotic degradation (Valera et al., 2013), enter the food chain, and accumulate in animal and human tissues (Almeida-González et al., 2012; Luzardo et al., 2012). Although the emissions of many POPs, such as organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs), were restricted 15 years ago under the Stockholm Convention due to their environmental persistency and toxic properties to humans and wildlife, many researchers still report detecting these legacy POPs in environmental and human samples all over the planet (Lee et al., 2014; Luzardo et al., 2014).

OCPs were the first group of synthetic organic pesticides used to minimize pest attacks. The first compounds of this group were introduced in the market in the early 1940s, but due to the concern about their toxicity and adverse effects on the environment, they began to be banned in the 1970s. Given their mainly agricultural nature, both in Spain and Morocco these pesticides were intensively used. However, two factors distinguish these two countries as regards to their potential background environmental contamination by OCPs. First, while in Spain the first ban of OCPs dates from 1977, in Morocco the same did not occur until almost a decade later (Kessabi et al., 1988). In fact, it has been estimated that during this decade apart the amount of OCPs used in Morocco exceeded 10,000 metric tons per year, and DDT accounted for 50% of this group (Benbakhta et al., 2014; FAO, 1986). But the second and more important difference is the existence of relevant obsolete pesticide stockpiles in the North African country, which do not exist in Spain. According to the inventory of the Food and Agriculture Organization of the United Nations (FAO), in 2010 more than 850 tons of obsolete pesticides were inventoried in 359 sites located in 8 regions of Morocco (http://www.fao.org/agriculture/crops/obsolete-pesticides). Only in one of these sites 300 kg of DDT and 1200 kg HCH were reported (El Morhit et al., 2013). Additionally some authors have indicated that, despite the ban, some extent of illegal use of OCP in agriculture might have existed and still continues in Morocco (Benbakhta et al., 2014).

Regarding the PCBs their origin is completely different as these compounds were widely used for industrial purposes for 50 years, and finally banned in 1979. Due to their chemical stability PCBs are still ubiquitous in the environment as pollutants. Despite their ubiquity throughout the planet, environmental concentrations in a particular region are conditioned by the past use of these chemical compounds in it. So it has been reported that in urban areas and in the most industrialized regions the levels of contamination by PCBs of the population are much higher than in rural areas (Ampleman et al., 2015; Marek et al., 2013). In this sense, Spain and Morocco are completely different, and therefore it is expected that the levels of contamination by these chemicals are also different. Thus, while according to the gross domestic product (GDP), the Spanish economy is the thirteenth in the world, with a strong industrial development (17% of GDP) and about 80% of the population living in big cities (UNIDO, 2014), the Moroccan economy is the typical of a developing country, with a growing but still emerging industrial development, and about 50% of the population living in rural areas (The-World-Bank, 2013). However, several studies have shown an increase in PCB sources in Africa due to leakage and wrongly disposed transformers, the increasing import of second-hand electronic and electrical equipment or directly of e-waste from countries of the North, shipwrecks, or biomass burning (Gioia et al., 2013).

The Canary Islands is a Spanish region, which belongs to the so-called outermost regions of the European Union due to their geographical position outside and far away the European continent. In fact this archipelago, although from historical, economic, political and sociocultural points of view is completely European, geographically is a part of the African continent, being just 100 km off the coast of Morocco (Fig. 1). Because of this the archipelago has been a target for the irregular immigration from Africa. Thus, it has been estimated that from 1999 to 2011 over 100,000 immigrants arrived by sea to the Canaries, and that more than 40% of them came from Maghreb countries (Rodríguez et al., 2008).

The population and environment of the Canary Islands have been extensively studied regarding their levels of legacy pollutants, and it has been reported that the levels of some of them (i.e. DDT and metabolites, cyclodienes, and in much lesser extent PCBs) could be considered as relatively high (García-Álvarez et al., 2014; Henriquez-Hernandez et al., 2011; Luzardo et al., 2006; Zumbado et al., 2005). As a plausible hypothesis it has been speculated that a possible cause for these high levels could be the proximity to the African continent and all its aforementioned peculiarities (García-Álvarez et al., 2014; Zumbado et al., 2005). But so far this hypothesis had not been tested, because as far as we know, no investigation on these residues in Moroccan population has been done, and studies on environmental samples in this country are very scarce.

As we had an exceptional opportunity to conduct the health assessments of many of the immigrants arrived to the Canaries, we designed this study, where we determined the levels of 10 OCPs and 18 PCB congeners in a series of 131 recently arrived immigrants from Morocco, who were voluntarily enrolled. Their levels of pollutants were compared with those of an equivalent series of long-term residents in the Canary Islands (n = 100), to have a glimpse of which can be the determinants of the contamination in both regions, and trying to disclose which is the influence of lifestyle in the level of contamination of these two populations from the same geographical area. In addition, this work constitutes the first report of the plasma levels of OCPs and PCBs in the population of Morocco.

2. Material and methods

2.1. Study population

The Moroccan study population consisted of 131 immigrants (117 men and 14 women, average age 27.1 ± 8.0 years old), who were sequentially and prospectively recruited within the first two months after their arrival on the island of Gran Canaria (Canary Islands, Spain). We recruited people who were temporarily lodged in shelters as part of the general screening for imported diseases. Physical examination and 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) was done as previously reported (Luzardo et al., 2014). Blood samples were obtained from all of the participants. First, blood samples were analyzed to determine immunological, hematological, biochemical, parasitological, and nutritional

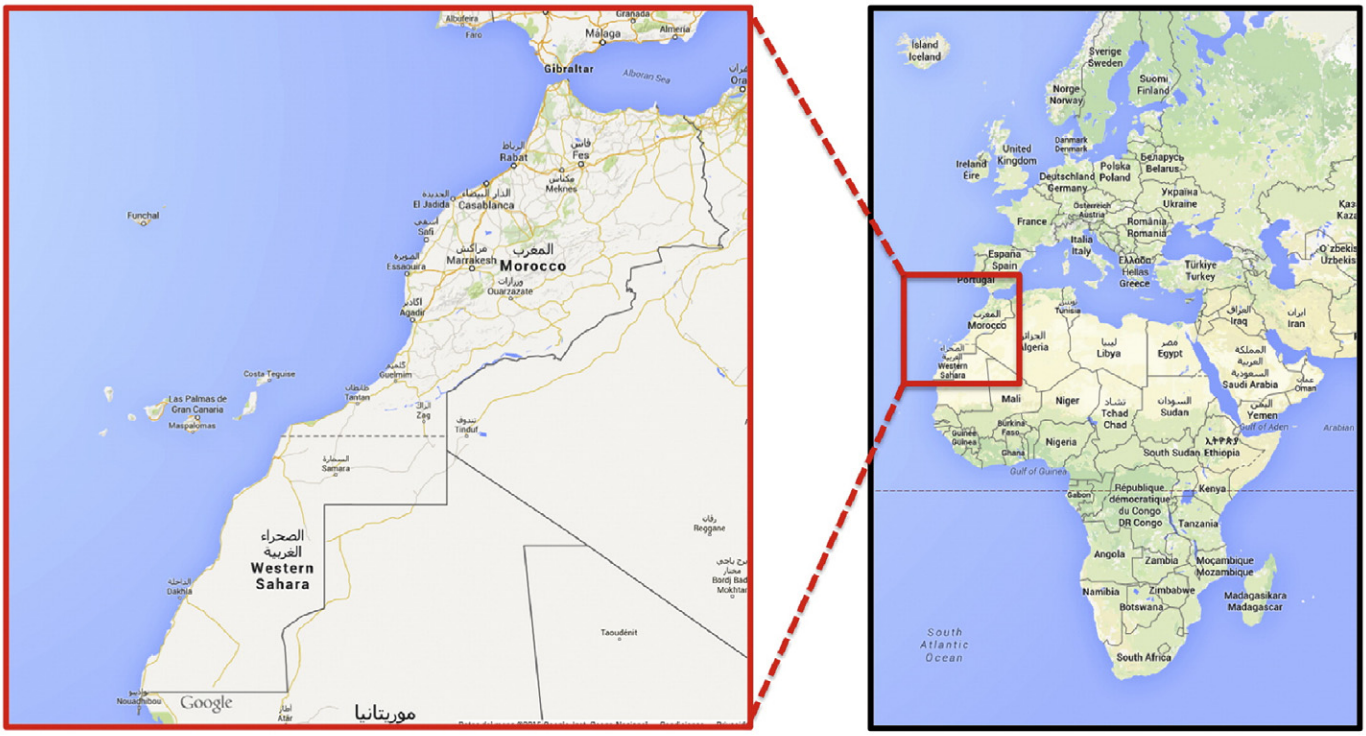

Fig. 1. Map of the location of the Canary Islands and Morocco. All participants were enrolled in Gran Canaria (100 Canarian and 138 Moroccan immigrants).

parameters. The remaining plasma was kept frozen at −80 °C until the POPs analysis was performed.

A total of 100 subjects from the Canary Islands were included in the study (60 men and 40 women, average age 34.1 ± 6.5 years old). The series was recruited from the Spanish Red Cross blood bank from October to December 2013. All participants were residents in Gran Canaria (Canary Islands, Spain) and determined to be eligible as blood donors based on the screening by nurses before recruitment. This study was approved by the Ethics Committee of our institution. For reasons of confidentiality, only age and gender was available.

Samples of blood were collected in heparinized tubes, maintained at 4 °C, and centrifuged at 1000 *g* for 15 min to separate the plasma. The obtained plasma was kept at −20 °C until chemical analysis.

2.2. Analytical chemical methods

We measured the plasma levels of 10 OCPs: hexachlorocyclohexane (isomers α-, β-, γ-, δ-HCH), p,p′-DDT, p,p′-DDE, p,p′-DDD, aldrin, endrin, and dieldrin. We also determined 18 PCB congeners, including marker-PCBs (M-PCBs) and dioxin-like PCBs (DL-PCBs): IUPAC numbers # 28, #52, #77, #81, #101, #105, #114, #118, #123, #126, #138, #153, #156, #157, #167, #169, #180, and #189.

The details of sample extraction, validated chromatographic method, and quality control have been previously reported (Camacho et al., 2013; Luzardo et al., 2013). Briefly, samples were subjected to solid-phase extraction using Chromabond® C18ec columns (Macherey-Nagel, Germany) that yielded recoveries in the range of 89–107%. Without further purification steps, the samples were subjected to chromatographic analysis on a Trace GC Ultra coupled with a Quantum Max triple quadrupole mass spectrometer (Thermo Fisher Scientific, Palo Alto, CA) for the quantification of the 28 analytes in addition to internal standards and surrogates. The instrumental limits of quantification (LOQs) ranged from 0.05 to 0.5 ng/ml for OCPs, and from 0.05 to 0.2 for PCBs, as previously described (Luzardo et al., 2013). A zero value was assigned to all the compounds below the limit of detection (LOD), and those compounds below the LOQ were assigned half of the LOQ. The total cholesterol and triglyceride concentrations were determined enzymatically and used for the lipid adjustment of results, as recommended (Bernert et al., 2007). Median total lipids were 7.6 g/L (p25-p75 = 6.5–8.3 g/L) for Canarian population, and 7.2 g/L (p25-p75 = 6.1–8.1 g/L) for Moroccans. Subsequently, all the results have been expressed in ng/g lipid weight (lw).

2.3. Quality of analyses and quality control (QA/QC)

All of the measurements were performed in triplicate, and we used the means for the calculations. In each batch of samples, three controls were included for every 18 vials (6 samples): a reagent blank consisting of a vial containing only cyclohexane; a vial containing 2 ng/mL of each of the pollutants in cyclohexane; and an internal laboratory quality control sample (QC) consisting of blank serum (Lyophilized human serum, Medidrug Basis Line, Medichem, Germany) spiked at 20 ng/mL of each of the analytes. The QC was processed using the same method as the plasma samples. The results were considered to be acceptable when the concentration of the analytes determined in the QC sample was within 15% of the deviation of the theoretical value.

2.4. Statistical analysis

We used PASW Statistics v 19.0 (SPSS Inc., Chicago, IL, USA) to manage the database of the study and to perform statistical analyses. The POPs distributions lacked normality and homoscedasticity; therefore, we used non-parametric tests. We used the chi-square test to examine the relationships between the categorical variables. The results were reported as medians and interquartile ranges. Probability levels of less than 0.05 (two tailed) were considered statistically significant.

3. Results and discussion

3.1. Concentrations of OCPs in canary residents and Moroccans

In this study we included the 10 most frequently detected OCPs in environmental samples, and as expected all of them were detected in the plasma samples of both study populations. However, for many of them we found significant differences in both the frequency of detection and, above all, in concentrations. In Table 1 we summarize the results of this group of contaminants.

The most frequently detected pesticides were p,p′-DDE and dieldrin in both populations (≥90% of subjects). Similar frequencies of detection were observed for all the pesticides, except for p,p′-DDD, which was more frequently detected in the residents in the Canaries than in Moroccans (34% vs. 9.2%, respectively; $p < 0.0001$). In a previous series of residents in the Canary Islands a lower percentage of detection of this metabolite of DDT was reported (20.4%) (Zumbado et al., 2005), but those samples were taken almost 20 years ago. It is therefore possible that the small increase observed for this metabolite has to do with the aging of environmental DDT including dechlorination to DDD, as it has been described (Thomas et al., 2008). We thought it interesting to note this result because it has recently been reported that the DDD is able to alter estrogen and androgen homeostasis at a cellular level (Rivero et al., 2015), and also that it may be involved in the development of breast cancer (Boada et al., 2012), and therefore this difference between Canarians and Moroccans could not be exempt from long-term toxicological significance for the first (Boada et al., 2012).

Unlike what happened with the detection frequencies, concentrations of OCPs were very different between the two populations. Thus, as seen in Table 1, mean and median levels of p,p′-DDE in the residents in the Canary Islands were 102.1 and 66.4 ng/g lipid respectively (Table 1). Notably, this value represents a reduction of nearly 50% compared to what was reported for this archipelago in samples taken 20 years ago (Zumbado et al., 2005). The current concentrations found in the Canary population are quite similar to those recently reported for the population of other Spanish regions (Alvarez-Pedrerol et al., 2009; Morales et al., 2013; Vrijheid et al., 2012). On the other hand, comparatively the levels of p,p′-DDE in the Moroccan study population were significantly higher (mean 367.8 ± 770.1 ng/g lw; median 107.2 ng/g lw, $p = 0.012$), but very similar to those reported in the Canary population in the last 1990s (median of p,p′-DDE = 118 ng/g lw) (Zumbado et al., 2005). Compared to other African regions, Moroccan subjects showed values of p,p′-DDE similar to those found in South African women from mining areas (488 ng/g lw), but lower than those reported in malaria endemic sites (Rollin et al., 2009). In a recent study we reported the levels of contamination by OCPs on people of different countries in Sub-Saharan Africa, an in comparison Moroccans' median plasma levels of p,p′-DDE are similar to those observed in people from Ivory Coast (188 ng/g lw), Guinea Bissau (129 ng/g lw) and Senegal (111 ng/g lw); but lower than those detected in people from Cameroon, Congo Republic or Equatorial Guinea (≥350 ng/g lw in all cases) (Luzardo et al., 2014). Taken together these results we see that there are large regional differences of the contamination by this pesticide in Africa, which have been attributed to different levels of socioeconomic development of the countries and other idiosyncratic factors (Luzardo et al., 2014; Rollin et al., 2009). However, in all cases the levels detected in the abovementioned and the rest of the previously studied sub-Saharan countries (Luzardo et al., 2014) were much higher than those in the Canaries. So it appears that, contrary to what was though, the levels detected in the inhabitants of the Canary Islands do not appear to be influenced by the proximity to Africa. It is noteworthy that the p,p′-DDE was the only compound in the group of DDTs which was statistically different between the two populations. The parent compound, p,p′-DDT, yielded very similar levels in both study groups (Table 1). In any case, the ratio of DDT/DDE was far less than 1 in both cases, suggesting an aging of environmental DDT in both territories, which would go against what some authors have suggested regarding the existence of a current illicit use of this pesticide in the North African country (Benbakhta et al., 2014).

In relation to the rest of the investigated OCPs we also found significant differences in the levels of dieldrin between the Canarians and Moroccans, being higher in the latter (Table 1). This pesticide, similarly to DDT, was intensively used in the agriculture as a soil insecticide worldwide. However, it is known that dieldrin was donated to African countries until the late 1980s to control plagues, which created numerous stockpiles in many countries including Morocco after its ban (FAO, 1998). This fact could explain the differences observed between the two populations. Although the studies in the North African country are scarce in the literature, a recent survey indicated that the contamination by pesticide residues, including dieldrin, is widespread in some agricultural areas of Morocco (El Bakouri et al., 2007). Besides, it should be noted that the current levels of dieldrin may be reflecting both, the past use of this pesticide, as well as the use of other similar compounds, such as aldrin or endrin, since it has been reported that both

Table 1
Plasma concentrations of organochlorine pesticides (ng/g lw) in permanent residents in the Canary Islands, Spain (n = 100) and Moroccans, recently arrived to the Canary Islands (n = 131).

	Canarian			Moroccan				
	Mean ± SD	Median (p25th–p75th)	Freq. (%)	Mean ± SD	Median (p25th–p75th)	Freq. (%)	P^*	$P^\#$
∑ *HCH*	4.9 ± 14.8	1.6 (0.0–3.2)	71.0	4.5 ± 11.2	1.6 (0.0–3.2)	70.2	0.940	0.508
HCH-alpha	0.1 ± 0.5	0.0 (0.0–0.0)	6.0	0.1 ± 0.5	0.0 (0.0–0.0)	5.3	0.831	0.524
HCH-beta	3.9 ± 12.9	1.6 (0.0–3.2)	60.0	3.2 ± 8.9	1.6 (0.0–3.2)	58.0	0.874	0.433
HCH-gamma	1.2 ± 4.1	0.0 (0.0–1.6)	29.0	0.9 ± 2.8	0.0 (0.0–1.6)	28.2	0.879	0.507
HCH-delta	0.9 ± 3.2	0.0 (0.0–0.0)	21.0	1.2 ± 4.3	0.0 (0.0–0.0)	21.4	0.880	0.539
∑ *DDT*	105.2 ± 120.8	68.0 (40.4–119.2)	98.0	381.0 ± 837.3	108.8 (30.4–363.2)	96.2	0.016	0.348
p,p′-DDT	1.9 ± 4.6	1.6 (0.0–1.6)	52.0	12.2 ± 102.9	0.0 (0.0–3.2)	49.6	0.483	0.411
p,p′-DDE	102.1 ± 119.6	66.4 (36.8–118.8)	98.0	367.8 ± 770.1	107.2 (28.8–361.6)	96.2	0.012	0.348
p,p′-DDD	1.3 ± 3.7	0.0 (0.0–1.6)	34.0	1.0 ± 5.7	0.0 (0.0–0.0)	9.2	0.0001	0.0001
∑ *Cyclodienes*	9.1 ± 7.9	7.3 (3.3–11.4)	93.0	42.7 ± 34.3	34.2 (21.2–58.7)	93.1	0.0001	0.584
Aldrin	0.2 ± 0.8	0.0 (0.0–0.0)	11.0	0.3 ± 0.9	0.0 (0.0–0.0)	10.7	0.981	0.552
Dieldrin	8.9 ± 7.5	6.5 (3.3–11.4)	91.0	42.4 ± 34.3	34.2 (17.9–57.1)	92.4	0.0001	0.444
Endrin	0.9 ± 3.3	0.0 (0.0–0.0)	21.0	0.9 ± 3.4	0.0 (0.0–0.0)	21.4	0.919	0.539
∑ *OCPs*	121.3 ± 130.3	83.4 (55.1–134.8)	99.0	430.2 ± 850.5	150.2 (63.0–433.8)	100.0	0.0001	0.433

Abbreviations: HCH, hexachlorocyclohexane; DDT, Dichlorodiphenyltrichloroethane; DDE, Dichlorodiphenyldichloroethylene; DDD, Dichlorodiphenyldichloroethane; SD, standard deviation; p25th–p75th, percentiles 25 and 75 of the distribution; Freq, frequency of detection.
* U Mann–Whitney test (comparison of medians among populations).
\# Chi square test (comparison of frequencies of detection among populations).

are rapidly converted into dieldrin in contact with the ground and the air (Groetfelty, 1978), and an intensive use of aldrin was reported in Morocco in the 1980s (Kessabi et al., 1988). Interestingly, in the case of the Canaries' inhabitants, the levels of these pesticides have decreased significantly compared to that reported two decades ago in the archipelago (Luzardo et al., 2006). While in the 1990s the levels of endrin and aldrin were reported to be high in the inhabitants of the archipelago (especially in the youngest people), currently these two pesticides are detected in virtually no sample, and only dieldrin is frequently detected (91%, Table 1), but at much lower levels than those previously reported (Luzardo et al., 2006). Although periodic intrusions of Saharan dust in the Canaries produce that high levels of particles are registered in the atmosphere of the archipelago several times a year (Baldasano et al., 2014), and the fact that the dieldrin has been recently detected in Saharan dust (Garrison et al., 2013), on the light of our results it can be concluded that the proximity to the African coasts does not seem to be major determinant of the levels of this pesticide in the inhabitants of these islands. In fact, not only the levels in the Canaries' residents were well below than those detected in the inhabitants of neighboring Morocco, but were also much lower than those of people from many other West African countries (Luzardo et al., 2014).

With respect to the rest of the OCPs included in this study we did not find any significant difference either in the concentrations or in the frequency of detection. However, the large differences in p,p′-DDE and dieldrin produced that $\sum$OCPs was also statistically higher in Moroccans than in Canaries' residents (Table 1, Fig. 2).

3.2. Concentrations of PCBs in Canary residents and Moroccans

It is well known that PCBs are toxic even at environmental concentrations. In fact, many relationships have been described between these contaminants and different pathologies, and even that small concentrations may induce subtle modifications in the human homeostasis (Henriquez-Hernandez et al., 2015).

It has been described that the levels of PCBs are increasing in Africa (Asante et al., 2011; Gioia et al., 2013; Luzardo et al., 2014), and also that in wildlife living in the vicinity of the Canary Islands an upward temporal trend has been observed (García-Álvarez et al., 2014; Luzardo et al., 2014), pointing to the possibility that nearby sources of contamination are present. For this reason we considered of interest to including in this study the determination of the more toxic and environmentally relevant suite of PCB congeners, and compare the levels between the residents in the Canary Islands and Moroccans. In Table 2 we show the results of this comparison. As it can be seen, the levels of almost all congeners were significantly higher in the inhabitants of the Canary Islands than in Moroccans.

The median levels of PCBs detected in the Canarian population ($\sum$M-PCBs = 45.6 ng/g lw; $\sum$DL-PCBs = 7.3 ng/g lw; and $\sum$PCBs = 53.8 ng/g lw; Table 2), despite being higher than those detected in Moroccans, are the lowest among the Spanish regions (Agudo et al., 2009; Huetos et al., 2014; Porta et al., 2012; Zubero et al., 2009). This is probably due to the fact that there is a limited presence of industrial sources of PCB in Canary Islands (Henriquez-Hernandez et al., 2011). In addition, it drove our attention the fact that the current levels of these contaminants in the residents in the Canary Islands are equal or even higher than those previously reported in a population sample taken in the 1990s in this archipelago ($\sum$M-PCBs = 46.4 ng/g lw; $\sum$DL-PCBs = 0.0 ng/g lw; and $\sum$PCBs = 48.2 ng/g lw; median values) (Henriquez-Hernandez et al., 2011; Huetos et al., 2014). Environmental exposures that affect accumulation of PCBs in humans are complex and not fully understood, and although one could expect a decrease of these banned contaminant along the years, the opposite has been already reported in other studies throughout the world (Diamond et al., 2010; Marek et al., 2013). Some authors have reported that after a steep decline in the environmental levels of PCBs, which followed the ban of these chemicals, their levels appear to be at or near a steady-state condition (Sobek et al., 2015). However, the possibility exists that new sources near the archipelago could be present, and that these contributed to maintain the PCBs at the same levels than 20 years ago, instead of decreasing.

In this sense, and similarly to what has been reported in other African countries (Gioia et al., 2013; Luzardo et al., 2014), new and recent sources of PCBs seem to be present in Morocco (Giuliani et al., 2015). Nevertheless, this does not appear to have yet a reflection in the levels of most of the PCB congeners in the Moroccan population, as these remain at very low levels according to the results of the present study (Table 2). However, some authors have shown that the increase in ambient levels of PCBs, particularly in sediments, have no immediate translation in the increasing of the levels detected in biota (Khairy et al., 2014), and therefore the picture could be completely different in a few years. As a glimpse of this, it is very interesting to note that the only congener that was significantly higher in Moroccans than in Canaries' residents was a trichlorobiphenyl, PCB #28 (Table 2), and that these congeners are those recently found at the highest concentrations in the surface layers of the sediments on a Moroccan lake, indicating recent deposition (Giuliani et al., 2015).

Therefore, the results of this study do not allow ruling out the possibility that the levels of PCBs are actually increasing in the area, and further studies are needed in the future to assess which is the real risk for both populations of these recalcitrant pollutants inherited from the past.

4. Conclusions

In the present study we compared the plasma levels of persistent organic pollutants in two populations, which are geographically very

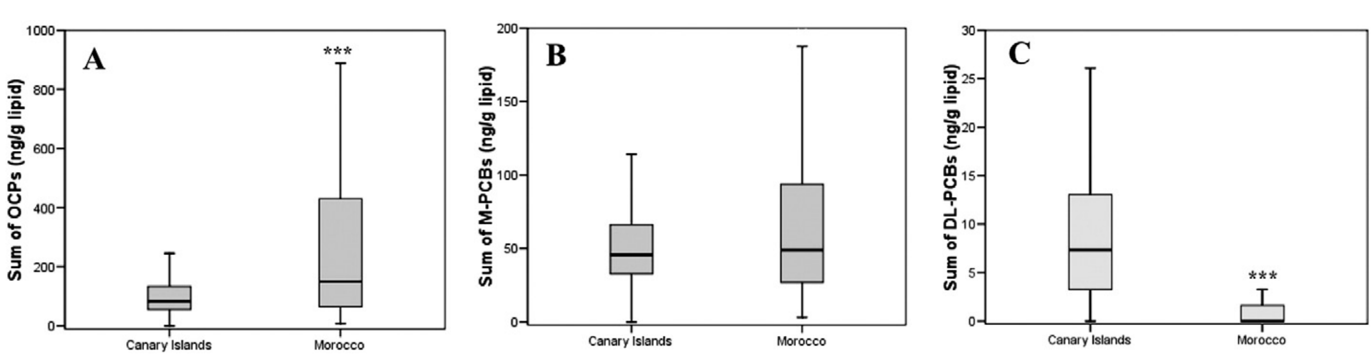

Fig. 2. Box plots indicating the comparison of the levels of OCPs (A), M-PCBs (B), and DL-PCBs (C). The line inside the box represents the median, the bottom and top of the box are the first and third quartiles of the distribution, and the lines extending vertically from the boxes indicate the variability outside the upper and lower quartiles. Sum of OCPs: HCH (isomers alpha-, beta-, gamma-, and delta-), p,p′-DDT, p,p′-DDE, p,p′-DDD, aldrin, dieldrin, and endrin; sum of marker PCBs: congeners 28, 52, 101, 138, 153, and 180; sum of dioxin-like PCBs: congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189.

Table 2
Plasma concentrations of polychlorinated biphenyls (ng/g lw) in permanent residents in the Canary Islands, Spain (n = 100) and Moroccan, recently arrived to the Canary Islands (n = 131).

	Canarian			Moroccan				
	Mean ± SD	Median (p25th–p75th)	Freq. (%)	Mean ± SD	Median (p25th–p75th)	Freq. (%)	P^*	$P^\#$
∑ *M-PCBs*	54.4 ± 38.2	45.6 (32.6–66.4)	99.0	83.3 ± 117.2	48.9 (26.1–96.2)	100.0	0.446	0.433
PCB 28	10.9 ± 8.1	8.9 (6.5–13.0)	98.0	21.0 ± 18.9	16.3 (8.2–27.7)	100.0	0.0001	0.186
PCB 52	5.2 ± 3.7	4.9 (1.6–6.5)	91.0	5.5 ± 5.6	3.3 (1.6–8.2)	85.5	0.295	0.143
PCB 101	9.2 ± 7.0	8.2 (4.9–12.6)	95.0	5.9 ± 7.4	3.3 (0.0–8.2)	74.0	0.0001	0.0001
PCB 138	6.8 ± 7.0	4.9 (3.3–8.2)	95.0	11.4 ± 32.0	3.3 (0.0–9.8)	69.5	0.028	0.0001
PCB 153	12.1 ± 11.3	9.8 (4.9–14.7)	97.0	25.5 ± 47.5	8.1 (3.3–29.3)	80.2	0.932	0.0001
PCB 180	8.1 ± 10.2	6.5 (3.3–9.8)	94.0	13.2 ± 31.4	4.9 (0.0–9.8)	66.4	0.036	0.0001
∑ *DL-PCBs*	14.7 ± 29.9	7.3 (3.3–13.0)	89.0	1.6 ± 3.4	0.0 (0.0–1.6)	34.4	0.0001	0.0001
PCB 77	1.3 ± 3.2	0.0 (0.0–1.6)	33.0	0.0	0.0	0.0	0.0001	0.0001
PCB 81	0.4 ± 1.1	0.0 (0.0–0.0)	14.0	0.04 ± 0.3	0.0 (0.0–0.0)	1.5	0.0001	0.0001
PCB 105	1.4 ± 1.9	1.6 (0.0–1.6)	52.0	0.1 ± 0.5	0.0 (0.0–0.0)	3.8	0.0001	0.0001
PCB 114	0.6 ± 2.3	0.0 (0.0–0.0)	17.0	0.05 ± 0.4	0.0 (0.0–0.0)	1.5	0.0001	0.0001
PCB 118	2.0 ± 2.5	1.6 (0.0–3.3)	70.0	0.7 ± 2.1	0.0 (0.0–0.0)	22.1	0.0001	0.0001
PCB 123	0.6 ± 2.6	0.0 (0.0–0.0)	16.0	0.04 ± 0.3	0.0 (0.0–0.0)	1.5	0.0001	0.0001
PCB 126	0.0	0.0	0.0	0.0	0.0	0.0	–	–
PCB 156	1.5 ± 2.6	0.0 (0.0–1.6)	47.0	0.6 ± 1.4	0.0 (0.0–0.0)	18.3	0.0001	0.0001
PCB 157	1.6 ± 2.8	1.6 (0.0–1.6)	54.0	0.0	0.0	0.0	0.0001	0.0001
PCB 167	1.1 ± 3.9	0.0 (0.0–0.0)	24.0	0.02 ± 0.3	0.0 (0.0–0.0)	0.8	0.0001	0.0001
PCB 169	2.3 ± 5.8	1.6 (0.0–1.6)	54.0	0.0	0.0	0.0	0.0001	0.0001
PCB 189	1.9 ± 4.7	1.6 (0.0–1.6)	52.0	0.06 ± 0.5	0.0 (0.0–0.0)	2.3	0.0001	0.0001
∑ *PCBs*	69.1 ± 63.7	53.8 (40.7–79.9)	99.0	84.9 ± 119.5	52.2 (26.1–96.2)	100.0	0.479	0.433

Abbreviations: PCB, polychlorinated biphenyls; M-PCBs, sum of marker PCB congeners; DL-PCBs, sum of dioxin-like PCB congeners; SD, standard deviation; p25th–p75th, percentiles 25 and 75 of the distribution; Freq, frequency of detection.
* U Mann–Whitney test (comparison of medians among populations).
\# Chi square test (comparison of frequencies of detection among populations).

close but which have completely different life styles: Canarians and Moroccans. Our results indicate that the plasma levels of such contaminants are deeply influenced by the inherited background contamination of both territories, more than by their geographical neighborhood. Thus the levels of OCPs (specifically p,p′-DDE and dieldrin) were higher in Moroccans than in Canarians, which would be a reflection of their more intense and recent exposure to these chemicals. On the other hand, in the Canary Islands, where these pesticides were discontinued almost a decade earlier and where stockpiles do not exist, the levels are significantly lower.

On the other hand, with the levels of PCBs (specifically DL-PCBs) the opposite occurred, i.e. that were higher among the inhabitants of Canary Islands than in the Moroccans, which might be related to the greater degree of industrialization and urban development of the archipelago. However, this work provides with some clues about that recent sources of PCBs in Morocco are having an impact in the levels of these chemicals in the population of this country, although overall levels remain low. In any case, our results clearly suggest that are lifestyle and the use in the past of these substances in each of these territories the main determinants of the levels of contamination found in the inhabitants, and that the vicinity of both territories is not a major determinant of each other contamination.

Conflict of interest

Authors declare no conflict of interest.

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