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Short communication

Total arsenic in marine organisms from Cienfuegos bay (Cuba)

Carlos Manuel Alonso-Hernández [a,*], Miguel Gómez-Batista [a], Misael Díaz-Asencio [a], Juan Estévez-Alvares [b], Román Padilla-Alvares [b,1]

[a] Centro de Estudios Ambientales de Cienfuegos (CEAC), AP5, Ciudad Nuclear, Cienfuegos, CP 59350, Cuba
[b] Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), Calle 30 #502 e/ 5ta y 7ma Avenida, Playa, Ciudad Habana, Cuba

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ABSTRACT

Levels of total arsenic were determined in muscle tissues of species of fish, crustaceans and molluscs from Cienfuegos Bay, Cuba. The arsenic content in the samples was determined using an energy dispersive X-ray fluorescence (EDXRF) method. The highest concentrations of total arsenic were found in crustaceans and average values for fish, molluscs and crustaceans were 10.2, 22 and 26.5 μg g^{-1} dry wt, respectively.

1. Introduction

Arsenic is ubiquitous in the environment: it is present in soil, water and living organisms. The natural content of arsenic present in soil and water depends on geological factors. Some species of marine plants and marine organisms have naturally high concentrations of arsenic. Anthropogenic activities, such as combustion of coal and oil, production of fertilisers and use of arsenical pesticides, contribute (with a significant portion) to the natural background.

The harmful effect of arsenic and its compounds on biological systems, coupled with its widespread distribution through natural or man-made sources, has encouraged many investigators to determine the levels of arsenic in the environment, especially in marine food.

Cienfuegos bay, situated in the southern part of Cuba, is a semi-enclosed bay, with a surface area of 90 km^2 and an average depth of 14 m. It is connected to the Caribbean Sea by a narrow channel 3 km long (Fig. 1). The bay is divided in two well defined hydrographic basins, due to the presence of a submerged ridge 1 m below the surface. The northern basin receives most of the anthropic impact from the outfall of Cienfuegos city (150,000 inhabitants), industrial pole in the country, and the freshwater input of Damuji and Salado rivers. The southern basin is subjected to a smaller degree of anthropic pollution, originating from the Caonao and Arimao rivers. Part of the southern basin is a natural park, which represents a niche for protected migratory birds and marine species.

The bay represents the most important natural resource in the province, due to fishing activities, maritime transport, tourism industry and natural parks. During the past decade it has acquired an important economic and social development, resulting in an increase of industrial and domestic wastes which are discharged into the bay. Direct input of arsenic to Cienfuegos Bay occurs through the nitrogen fertiliser factory, which was authorised to release arsenic residuals up to 1981 and where two accidental As spills took place in 1979 and 2001.

Marine organisms represent an important component of the diet of the population of Cienfuegos. In particular, people from the coastal areas of Castillo de Jagua, Las Minas and O'bourque have an average ingestion rate of fish of 51 kg yr^{-1}, varying from 21 to 116.

Only a few studies have investigated the total As content in marine organisms from Cuba. In particular, a survey of marine products from the western coast, displayed concentrations of arsenic ranging from 0.01 to 4.82 μg g^{-1} d.w. (Beltran, Syminton, Dominguez, Amalia, & Roch, 1988). Total arsenic in fish and crustaceans was also measured in Cienfuegos Bay in 1974 and results showed low concentrations of this compound (1.2 μg g^{-1} d.w. in fish and 1.7 in crustaceans).

As part of a baseline study, aimed to aid the development of a management programme for Cienfuegos bay, biological, chemical

* Corresponding author. Tel./fax: +53 43 965146.
E-mail addresses: carlos@ceac.cu (C.M. Alonso-Hernández), miguel@ceac.cu (M. Gómez-Batista), misael@ceac.cu (M. Díaz-Asencio), jestevez@ceaden.edu.cu (J. Estévez-Alvares), padilla@ceaden.edu.cu, r.padilla@iaea.org (R. Padilla-Alvares).
[1] Present address.

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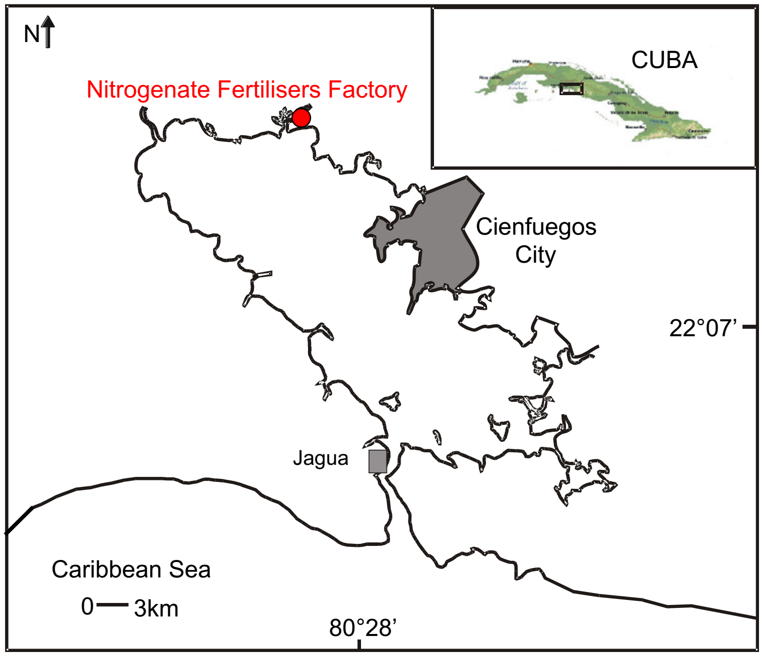

Fig. 1. Location of the study area.

and physical investigations have been undertaken since 1999. The results of these studies showed an increase of total arsenic in sediments from the northern basin during the past three decades.

In this paper, the arsenic content of some fish, crustaceans and oysters from Cienfuegos Bay is presented.

2. Materials and methods

2.1. Samples

Fourteen species of fish, two of molluscs and three of crustaceans were caught in Cienfuegos bay. The target species were selected among those of dietary importance for the population (Alonso-Hernandez, Diaz-Asencio, Munos-Caravaca, Suarez-Morell, & Avila-Moreno, 2002) and are listed in Table 1.

The muscle tissue of each fish was obtained by filleting the organism, taking care not to penetrate the viscera and removing all skin and bony elements. The edible portion of each shellfish and crustacean was also removed from the shell. All tissues were minced, freeze-dried, ground and stored in closed jars prior to analysis.

2.2. Analytical procedure

All samples were sent for analysis to the Chemical Laboratory of Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear. This laboratory has been accredited by the Accreditation National Office body of the Republic of Cuba, since 1992, according to the ISO Guide-25 (this year the Laboratory is undergoing the accreditation process for ISO 17025).

The arsenic content in the samples was determined using an energy dispersive X-ray fluorescence (EDXRF) method (Si/Li detector with 180 eV for Mn Kα and Cd-109 annular source). The elaboration of the spectra and quantitative analysis was carried out by employing the QSAX System (IAEA, 1995). Compton peak was used for the matrix effect corrections. Several biological certified reference materials (NRCC DOLT-2 dogfish liver, NRCC TORT-2 lobster hepatopancreas, NIES CRM-9 *Sargassum* sp., NRCC DORM-1 dogfish muscle and IAEA-140/TM *Fucus* sp.) were measured for calculating the As concentrations in the samples.

Table 1
Analysed species with their Latin, Spanish and English names.

	Fish	Molluscs	Crustaceans
1.	*Albula vulpes* (Macabi/Bonefish)	*Isognomom alatus*	*Litopenaeus schmitti* (Camaron Blanco/White Shrimp)
2.	*Caranx hippes* (Jiguagua/Crevalle Jack)	*Crassostrea virginica* (Ostion/Oyster)	*Farfantepenaeus notialis* (Camaron Rosado/Pink shrimp)
3.	*Centropomus ensiferus* (Robalo/Swordspine)		*Callinectes sapidus* (Jaiba/Blue crab)
4.	*Chloroscombrus chrysurus* (Casabillo/Atlantic Chrysurus)		
5.	*Diapterus auratus* (Mojarra/Striped Mojarra)		
6.	*Eucinostomus havana* (Mojarra/Bigeye Mojarra)		
7.	*Haemulon macrostomum* (Ronco/Spanish grunt)		
8.	*Harengula clupeola.* (Sardina escamuda/False herring)		
9.	*Kyphosus sectatrix* (Chopa/Bermuda sea-chub)		
10.	*Lutjanus synagris.* (Bijaiba/Lane snapper)		
11.	*Micropogonias furnieri* (Corvina/Whitemouth croaker)		
12.	*Mugil curema* (Plateado/White mullet)		
13.	*Ocyurus chrysurus* (Rabirubia/Yellowtail snapper)		
14.	*Sphyraema guaguancho* (Guaguancho/Guaguanche)		

Table 2
Concentrations of arsenic in fish, molluscs and crustaceans from Cienfuegos bay.

	n	Mean (μg g^{-1} d.w)	Range (μg g^{-1} d.w)	Values* 1974 (μg g^{-1} d.w)
Fish				
Albula vulpes	13	13.33	10–15	
Caranx hippes	12	2.66	2.17–3.15	
Centropomus ensiferus	12	11.75	8.5–15	
Chloroscombrus chrysurus	16	3.67	2.6–4.5	0.7–1.3
Diaterus auratus	11	4.10	2.1–5.6	
Eucinostomus havana	12	4.85	4.7–5	
Haemulon macrostoma	13	28.4	26.7–33	
Harengula clupeola	13	6.57	3–11.5	
Kyphosus sectatrix	11	5.30	2.3–11.2	
Lutjanus synagris	13	14.7	6.9–24	
Micropogonias furnieri	15	10.4	2.95–25	0.9–1.2
Mugil curema	15	16.6	9–42.6	
Ocyurus chrysurus	10	2.09		
Sphyraema guaguancho	10	2.59	2–3.12	
Molluscs				
Isognomom alatus	10	21	19–23	
Crassostrea virginica	10	23	21–25	
Crustaceans				
Litopenaeus schmitti	14	15.6	10–18.3	1.3–1.7
Farfantepenaeus notialis	17	24.3	14.9–29.5	1.5–1.9
Callinectes sapidus	15	36.2	6.9–53.9	

* Range of total arsenic in some marine organisms collected from Cienfuegos bay in 1974.

The quality of the analytical results was controlled according to the procedure, PE-Q-AQ-6 established in the laboratory since 1995. It consists in the repetition of the analysis of half the number of the samples (if $n < 20$) and in the introduction of one certified reference material. This procedure was elaborated based on the international experiences (ISO, 1991; Thompson & Wood, 1995).

3. Results and discussion

Results of total arsenic in the dissected parts of fish, molluscs and crustaceans from Cienfuegos Bay, are presented in Table 2. Data recorded in 1974 (CPHE, 1974) in some marine organisms from the area are also included in this Table. The data show significant differences in arsenic concentrations between the examined groups.

The highest values of arsenic were found in crustaceans, which showed a mean value of 26.5 μg g^{-1} d.w. (values ranging from 6.9 to 53.9). These levels are in agreement with others observed in literature for shrimps and marine crabs captured in estuaries and enclosed bays (Jewett & Naidu, 2000; Miao, Woodward, Swenson, & Li, 2001; Suñer et al., 1999). The higher arsenic content in tissues of bottom-dwellers, such as shrimps and crabs, can be attributed to their habitat being close to the sediment. Sediments are always higher in arsenic than water, and bottom water usually has a higher As concentration than has surface water (Byrd, 1988; Trembley & Gobeil, 1990).

When comparing the obtained values from this study with those reported in 1974 for shrimps from Cienfuegos bay, we observed that the mean value of arsenic in crustaceans was 18 times higher than at the earlier time. This could be explained through the increase of anthropogenic activity in the area during recent decades, when artificial sources of As were established in the coastal zone. In particular, the routine and accidental release of arsenic residuals from the nitrogen fertiliser factory could be responsible for the observed pattern.

In the fish muscle, the mean As concentration was 10.2 μg g^{-1} d.w. (values ranging from 2 to 42.6). These results are considered to be characteristic for normal or naturally altered areas. The international reports consulted (Eisler, 1981; Khudre, Zamil, Rawdah, & Tawabini, 1992; Suñer et al., 1999) indicate that marine fish can reach total As contents up to 150 μg g^{-1} d.w., without any risk for the population that consumes it. However, as for the crustaceans, the arsenic levels obtained in this study are 12 times higher than those reported in fish from Cienfuegos bay in 1974, and are considerably larger than those reported by Beltran et al. (1988) in fish captured from western Cuba.

With regard to the two molluscs analysed, the observed mean value was 22 μg g^{-1} d.w. This is similar to those obtained for the same species in a study carried out in the USA (Valette-Silver et al., 1999), where oysters collected along the coast, stretching from North Carolina to Florida showed high concentrations of As in their soft tissues.

The comparison of recent with previous data, strongly suggests that, during the past 30 years, Cienfuegos bay has been impacted by releases of arsenic residuals from the nitrogen fertiliser factory and possibly from other artificial sources present in the area.

From the public health point of view, many consider that high concentrations of As in marine food do not represent a serious threat, since only 2–10% of the total content is present in a potentially toxic inorganic form. The remaining part of the total As content (90–98%) is found in a highly stable and physiologically inactive organic form which is excreted in the urine (Friberg, 1988; Johnson & Farmer, 1991).

However, data related to arsenic speciation in marine organisms from Cienfuegos bay are not yet available, hence, concrete evaluations of As impact on human health are not possible.

Future studies will concentrate on the spatial/temporal distribution of As in marine organisms and sediments from Cienfuegos bay and will focus on the speciation of this element to provide more accurate data on its environmental and human health implications.

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