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# Chlorinated pesticides in the bodies of dolphins of the French Mediterranean coastal environment

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**Abstract**. The concentrations of organochlorinated pesticides including lindane, heptachlor, aldrin, heptachlor-epoxide, endosulfan I, dieldrin, and endrin were determinated in striped dolphins (*Stenella coeruleoalba*) (n = 26), and 2 bottlenose dolphins (*Tursiops truncatus)* (n = 2), stranded on the French Mediterranean coasts. Studies are carried out on the lung, the muscle, the kidney, the liver, and the blubber. The concentrations of all the analysed compounds were detected to variable levels in each tissue and organ. In blubber, dieldrin is generally the most abundant coumpound (215.3 ± 290.3 ng $g^{-1}$ lw), followed by endrin (207.7 ± 217.5 ng $g^{-1}$ lw), heptachlor-epoxid (106.6 ± 107.1 ng $g^{-1}$ lw), endosulfan I (46.6 ± 32.8 ng $g^{-1}$ lw), lindane (16.6 ± 12.1 ng $g^{-1}$ lw), aldrin (11.9 ± 8.4 ng $g^{-1}$ lw) and heptachlor (6.7 ± 4.2 ng $g^{-1}$ lw). These values are comparable to those previously obtained by other authors during the years 1990.

**Key Words**: Organochlorinated pesticides, organs, striped dolphins, bottlenose dolphins, Mediterranean Sea.



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## Introduction

Contamination pattern of any marine environment contains a wide variety of compounds, being the most dangerous non-biodegradable substances. The organochlorinated pesticides are of great concern because the high distribution of their residues in the aquatic ecosystem and because of their toxic and carcinogenic properties (Iwata *et al* 1993). Due to their toxicity, their persistence (Drinker *et al* 1937; Hutzinger *et al* 1974; Mackay *et al* 1992; Ulbrich & Stahlmann 2004) , their hydrophobic nature and their low solubility in water, the chlorinated pesticides are adsorbed on the particulate matters and finally in sediment. The chlorinated pesticides enter in the environment through human activities and various others pathways like atmospheric and fluvial transport. In particular they reach in the marine environment from the urban waste, the deposits of the waste cleaning plants, the agricultural cultivations as well as rinsing of the soils through flows.

MacKay *et al* (1992) reported that the half-life of pesticides ranges is approximately from 8 months to 6 years depending on the compounds. Despite their hydrophobicity, the immense volume of water in the oceans is capable to dissolve a significant quantity of pesticide. Moreover, industrial or accidental discharges can be transported and dispersed until oceans by rivers. After release in the natural environment, the pesticides are strongly accumulated by organisms which succeed one another in the food chain (Nakata *et al* 1998; Tanabe *et al* 1994a, 1994b). Organisms being at the top of the food chain (such as cetaceans) store large quantities of these pollutants (Poster & Simmonds 1992; Tanabe *et al* 1994a). Thus, cetaceans can be considered as actual indicators of the level of contamination of their natural environment. The organochlorinated compounds, combined with the degradation of the habitat of these marine mammals are widely suspected to contribute to their stranding and continued decline of their populations (Alzieu & Duguy 1979; Borrell *et al* 2001). Since the early seventies cetaceans have been protected and most of the data found in the literature refer to biopsies or to cetaceans stranded on beaches or unfortunately trapped in fishing nets. These studies have indicated high levels of pesticides in tissues and organs of cetaceans from the Mediterranean Sea (Alzieu & Duguy 1979; Aguilar 1987; Kannan *et al* 1993; Corsolini *et al* 1995; Marsili & Forcardi 1996; Aguilar *et al* 1999) and also, from other seas of the globe (Tanabe *et al* 1987; 1994a, 1994b; Nakata *et al* 1998; Ylitalo *et al* 2001; Wolkers *et al* 2008).

In this work, we report levels of pesticides: lindane, heptachlor, aldrin, heptachlor-epoxide, endosulfan I, dieldrin, and endrin in some cetaceans stranded on the French Mediterranean coasts between 2007 and 2009. The studies are achieved on the blubber, the liver, the muscle, the kidney, and the lung of the cetaceans. The samples are represented by 26 striped dolphins (*Stenella coeruleoalba*), and 2 bottlenose dolphins (*Tursiops truncatus*). One of the objectives of this study is to assess the current status of the dolphins'contamination by organochlorine compounds, in the French Mediterranean coastline region. We have also examined the repartition of the contamination in the different organs studied and compared the level of contamination according to age and sex.

## Materials and Methods

### Sampling and storage

The 26 specimens of *Stenella coeruleoalba* and the 2 T*ursiops truncatus* (code 17 and 54), (Table 1) studied in this work, were

Table 1. Code and characteristics of the studied dolphins; lipid content and concentrations (ng.g$^{-1}$ lw) of organochlorine compounds in the blubber of the studied dolphins (*Stenellas coeruleoalba* expected "17" and "54": *Tursiops truncatus*)

| Code | Year | Area | Sex | Length (cm) | Lipid (%) | Lindane | Heptachlor | Aldrin | Heptachlor-epoxid | Endosulfan | Dieldrin | Endrin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **21** | 2007 | Marseille | M | 210 | 66.8 | 18.1 | 11.5 | 29.7 | 226 | 72.9 | 139.8 | 89.2 |
| **24** | 2008 | Marseille | M | 221 | 79.3 | 14.2 | 1.9 | 15 | **21.3** | 80.2 | 207.3 | 104.2 |
| **25** | 2008 | Carry | M | 195 | 69.5 | 7.4 | 4.6 | 10.7 | 100.8 | 27.5 | 4.8 | 30.4 |
| **26** | 2008 | Sète | F | 147 | 72.7 | 11.9 | 10.3 | 9.6 | 28.9 | 89.6 | 9.3 | 67.8 |
| **28** | 2008 | Gruissan | M | 155 | 56.9 | 17.4 | 7.1 | 9.8 | 95.4 | 62.1 | 91.1 | 52.8 |
| **29** | 2008 | Marseillan | M | 197 | 26 | 10.3 | 17.2 | 1.9 | 32.5 | 14.1 | 122.3 | 62.9 |
| **30** | 2008 | Cassis | M | 110 | 63 | 11.3 | 2.8 | 17.2 | 14.4 | 4.6 | 60.1 | 10.7 |
| **31** | 2008 | Porquerolles | M | 193 | 70.6 | 23.3 | 14.1 | 16.5 | 63.4 | 22.7 | 13.4 | 44.4 |
| **33** | 2008 | Marseille | M | 99 | 53.1 | 7 | 3.1 | 3.2 | 51.3 | 12.3 | 17.6 | 63.5 |
| **36** | 2007 | Cannes | F | 200 | 55.9 | 19 | 2.8 | 3.3 | 21.2 | 11.8 | 218.3 | 169 |
| **40** | 2007 | Les Issambres | F | 220 | 53.1 | 60.1 | 12.7 | 10.7 | 75.7 | na | 9.9 | 67 |
| **41** | 2008 | Hyères | M | 163 | 36.4 | 19.1 | 2.5 | 21.2 | 32.2 | 26.9 | 486.2 | 314.4 |
| **42** | 2008 | Grimaud | M | 100 | 46.5 | 19.6 | 9.3 | 31.3 | 416.4 | 134.2 | 756 | 553.7 |
| **43** | 2008 | Cannes | M | 155 | 67 | 11 | 4.7 | 8.8 | 79.1 | 39.8 | 13 | 472.1 |
| **51** | 2008 | St Tropez | F | 190 | 30.7 | 3.2 | 2.5 | 3.2 | 4.8 | 20 | 16.2 | 6.1 |
| **55** | 2007 | Ramatuelle | F | 105 | 63.6 | 20.6 | 12 | 16.6 | 78.8 | 47.6 | 6.8 | 50.4 |
| **56** | 2008 | Arles | M | 197 | 48.3 | 13.9 | 8.2 | 9.8 | 32.5 | 37.9 | 131.2 | 62.7 |
| **57** | 2008 | Ste Maxime | M | 110 | 69.7 | 18.5 | 11.1 | 13 | 226.1 | 71.1 | 94.6 | 71.3 |
| **58** | 2007 | Cannes | F | 143 | 35.7 | 11.4 | 4.5 | 16.2 | 201.3 | 94.1 | 1009.3 | 1101.6 |
| **59** | 2007 | Cannes | F | 212 | 51.3 | 50.5 | 7.9 | 31 | 416.5 | 102.7 | 2509.5 | 15261 |
| **63** | 2007 | Nice | M | 163 | 63.7 | 9.3 | 5.2 | 4.7 | 80.3 | 29.1 | 26.3 | 272.6 |
| **68** | 2008 | Cap Ferrat | F | 145 | 56.9 | 12.1 | 4.8 | 8.6 | 154.9 | 53.9 | 321.9 | 493.2 |
| **69** | 2008 | Théoule | F | 144 | 67.1 | 10.1 | 1.7 | 4.2 | 59.8 | 20.8 | 13.1 | 22.3 |
| **70** | 2008 | Monaco | M | 150 | 46.5 | 15.7 | 4.9 | 9.8 | 163.8 | 55.8 | 537.7 | 644.2 |
| **71** | 2008 | Cannes | M | 207 | 47 | 5.1 | 4.6 | 2.7 | 66.9 | 19.2 | 534.6 | 228 |
| **72** | 2009 | Antibes | M | 160 | 39.6 | 10.1 | 1.6 | 1.5 | 28.1 | 12.9 | 7.7 | 133.2 |
| **17** | 2007 | Stes Maries | M | 159 | 46.9 | 38.7 | 14.5 | 30.8 | 41.1 | 75.2 | 62.1 | 58 |
| **54** | 2008 | Sausset pins | M | 270 | 42.8 | 29.5 | 31.9 | 86.6 | 117.6 | 28.9 | 236.6 | 194.5 |

M = Male. F = Female. na = not analyzed

found stranded, along the French Mediterranean coast (Figure 1) between 2007 and 2009.

The collection of tissues and organs was performed by the French Mediterranean Cetacean Study Group (GECEM), represented by Dr. Franck Dhermain (Dhermain *et al* 2011). Mammals are measured beforehand and possibly weighed. After dissection, the tissues and organs are delicately sampled and wrapped in aluminum foil and placed in an ice bath and then frozen at -20°C. Before analysis, the tissues and organs are lyophilized, pulverized and homogenized, stored in little airtight vials at 4°C. The collection of the samples started before the beginning of this study, so all the organs of all the dolphins had not been sampled. The samples were analyzed for the following compounds: lindane (HCH), heptachlor, aldrin, Heptachlor-epoxide, endosulfan I, dieldrin, and endrin.

Results in the blubber are expressed in ng/g lipid weight (ng g$^{-1}$ lw); while, in all other tissues and organs, they are expressed in ng/g dried weight (ng g$^{-1}$ dw).

**Extraction and quantitative analysis**

The glassware used have been cleaned before with an appropriate detergent and then dried at 200°C for at least 24 hours, and rinsed at least twice with the solvent (hexan), before use. Whatman cellulose thimbles (22-80 mm, no.350211, Schleicher and Schuell) used for extraction of samples were pre-extracted for 12 h in a soxhlet apparatus with hexane Pestipur (Pestipur 99%, SDS, Peypin, France), in order to remove any organochlorine contamination.

About 1g of freeze-dried sample was extracted with hexane in the thimbles of a soxhlet apparatus for at least 16 hours. The obtained solution was concentrated to 3 mL; from which 1 mL was taken to determine the content of lipid. The second part was twice purified with concentrated sulfuric acid, according the procedures described by (Murphy 1972), and the resulting extract was concentrated to 1 mL. Then the extract underwent liquid chromatography on a column containing silica gel and alumina following the procedures described by (Wafo *et al* 2005). Analyses were performed with a HP 6890 series gas chromatograph equipped with a 63Ni electron capture detector (ECD) at 300°C and an automatic injector on-column, HP 6890 series.

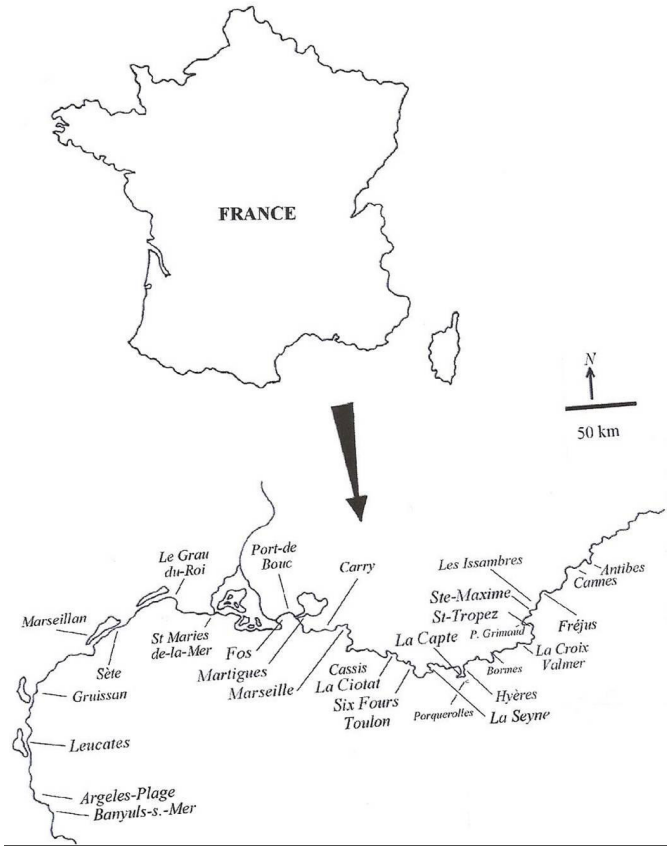


Figure 1. Map showing principal sampling locations

The column used was a DB5 J & W (60 m x 0.32 i.d. x 0.25 µm). The carrier gas was helium. The temperature of injection was 60° C and was programmed to increase up to 250° C at 100°C/min. The column temperature was 60°C and programmed to increase first up to 160°C (10°C/min) and then up 280°C at 2°C/min. The variation in the response of the ECD detector was corrected by a daily calibration with a standard solution of pesticides. Octochloronaphtalen (OCN) is used as internal standard. The sample response was matched to that of the standard solution by dilution or concentration of the sample.

**Lipid determination**

1.0 mL of the aliquoted extraction residue is introduced in an initially tared container and deposited into a desiccator. After drying to constant weight, the lipid content is determined by gravimetry.

**Quality control**

All the analyses were performed in our laboratory which owns a Cofrac accreditation n°1-1234 since 2001. The laboratory participates regularly to interlaboratory comparison exercises and data from our laboratory were in good agreement with those of reference materials.

For this study, we used, as certified material, an IAEA/UNEP intercomparison sample of Tuna homogenate (IAEA-435), which was distributed to world-wide laboratories in October 2004 (Villeneuve *et al* 2006). In each batch, a blank and a certified material were systematically introduced in order to validate the results obtained. For quality insurance and quality control, all the pesticides were analyzed as detailed previously. The results obtained for the reference materials were used to plot control charts and to decide upon acceptance or rejection of the data produced for each sample batch. Rejected batches were reanalyzed.

Ten replicated of IAEA 435 were conducted in the same day, in order to determine the average recovery for each pesticide: results varied from 84.8 and 101.2%.

The detection limit is to 0.1 ng/g for pesticides taking into consideration the lowest calibration level of a particular analyze and the amount sample extracted.

## Results and Discussion

A number of 39 cetaceans have been studied in this work: 26 *Stenella coeruleoalba* and 2 *Tursiops truncatus*. Since the dolphins' teeth were not sampled by the GECEM, the sexual maturity has been determinated according to the data of Alzieu & Duguy (1979) and Cardellicchio *et al* (2002). For *Stenella coeruleoalba*, there were 19 males, 13 females and 5 young dolphins. For *Tursiops truncatus*, there was 1 male and 1 young dolphin. The size and sexual maturity of these individuals as well as the date and place of stranding are presented in Table 1.

For each specimen, all the organs had not been sampled that is why they have not been analyzed in this study.

Organochlorines are very lipohiles compounds so they are mainly accumulated in the blubber. We chose to study this tissue separately from the other organs in order to facilitate the interpretation and to allow an easier comparison with results from other works.

**The pesticides in blubber of *Stenella coeruleoalba***

Concentrations of pesticides measured in blubbers of *Stenella* are always detected but are very low in some cases (Table 1). The average concentrations vary from one organism to another. The heptachlor-epoxide, dieldrin, endrin have average concentrations higher than 70 $ng.g^{-1}$ lw for all organisms (youngs, males and females). These values remain relatively low compared with those reported in the literature. Borrell & Aguilar (2007), in a study on Mediterranean dolphins, have reported levels for dieldrin superior to 1,500 $ng.g^{-1}$. On the other hand, levels of dieldrin ranging from 256 to 1,420 $ng.g^{-1}$ were measured for dolphins in India (Fair *et al* 2010), and levels ranging from 2,214 to 4,100 $ng.g^{-1}$ for dolphins originating from Australia by Ruchel (2001).

The endosulfan shows levels varying between 4.6 and 134.2 $ng.g^{-1}$ lw with an average level under 60 $ng.g^{-1}$ lw.

The levels of aldrin, heptachlor and lindane are in general low in all organisms. They vary from 1.5 to 60.1 $ng.g^{-1}$ lw, for an average level under 25 $ng.g^{-1}$ lw. The coefficient of distribution octanol-water (log Kow) of the dieldrin is in the order of 3.6-6.2 (Ritter *et al* 1996) and is equivalent to the coefficients of tetra-polychlorinated biphenyls (MacKay *et al* 1992). Dieldrin is a metabolite of aldrin (Edwards 1973). In the same sample, the dieldrin, unless exception is often in high proportion compared with aldrin, reflecting certainly the presence of this compound in the medium since a long time. Nevertheless, in organisms, due to microbiological activities, the dieldrin may in turn be transformed into aldrin (Kitamura *et al* 1999).

By contrast, we have mesured contents in endrin varying from 6 to 1,526 $ng.g^{-1}$, in blubber. These values are relatively high compared to the former pesticides and are comparable to those obtained by Hensen *et al* (2004) respectively 582 to 1,101 $ng.g^{-1}$. All these data reflect the persistent nature of the organic compounds in the environment. Some of them, like lindane or dieldrin are particularly toxic for many aquatic species from the

early stages of the life. In the marine organisms these recalcitrant compounds, associated with many other toxics compounds can lead to the suppression of immune defense (Jepson *et al* 2005), can affect reproduction (Wells *et al* 2005), and may even generate tumors (Martineau *et al* 1999).

In synergy with others chlorinated compounds as polychlorinated biphenyls, they are suspected to contribute to the strandings of dolphins.

A study of the relationship of the levels in males/females and young/females show that:

- The ratios of adult male (M) to female (F), $R_{(M/F)} > 1$ for aldrin and heptachlor. For all the other compounds, $R_{(M/F)} < 1$, which is to say that in blubber, adult females seem to accumulate preferentially some compounds as compared to others.
- The ratios young (Y) to female adult (F), $R_{(Y/F)} > 1$ for heptachlor, aldrin, heptachlor-epoxid, endosulfan. For the other compounds (lindane, dieldrin, endrin), the females seem to collect them more than the young dolphins and the adult males.

All these information require however a thorough study and on a higher sampling, to be validated.

**Pesticides in blubber of *Tursiops truncatus***

In principle, the *Tursiops truncatus* is a coastal species and thus is more confronted to strong pollution than *Stenella coerroleoalba* wich is a pelagic dolphin.

The comparison of results of other pesticides between the *Tursiops truncatus* (Table 1, n° 17 and 54), and *Stenella coeruleoalba* show no significant differences in pronounced accumulation between the two species. Kajiwara *et al* (2004) and Leonel *et al* (2010) report similar results in other species of cetaceans.

In the *Tursiops truncatus*, Fair *et al* (2010) have obtained levels of 1,230 to 1,650 $ng.g^{-1}$ lw in dieldrin. These contents are comparable to those obtained by Borrell & Aguilar (2007), in the dolphins of the Mediterranean Sea. Nevertheless, this comparison must be tempered, because only two specimens of *Tursiops truncatus*, was studied here. Moreover, it's a little premature runt, which was never suckled, and never caught preys, which is not the case of the specimens of *Stenella coeruleoalba*.

**Pesticides in the different organs for *Stenella coeruleoalba***

We have quantified each of the pesticides listed above in most of our samples of striped dolphins. The average concentrations for each compound in the different tissues and organs are given in the Table 3 considering young, male and female dolphins respectively.

Results show that, few significant differences appear between juveniles and adults, at the level of total contents in the various organs. We note that, the young dolphins already contain relatively important levels of organochlorinated pesticides.

In all the tissues and organs, for young dolphins and adult, the overall average contents vary approximatively in the same way as in the blubber: dieldrin and endrin are the predominant compounds with some exceptions (for instance, a very low level of dieldrin in the lung of young dolphins). The levels of heptachlor and aldrin are the lowest in most of the samples. The levels of lindane, heptachlor-epoxide and endosulfan I are in general between the two previous "categories".

We have established the ratios of concentration between male (M) and female (F) $R_{(M/F)}$, then between young (Y) dolphins and females $R_{(Y/F)}$ and finally between young and male $R_{(Y/M)}$; the aim being to understand the behavior of pesticides in the different organs. Results are presented in Figure 2.

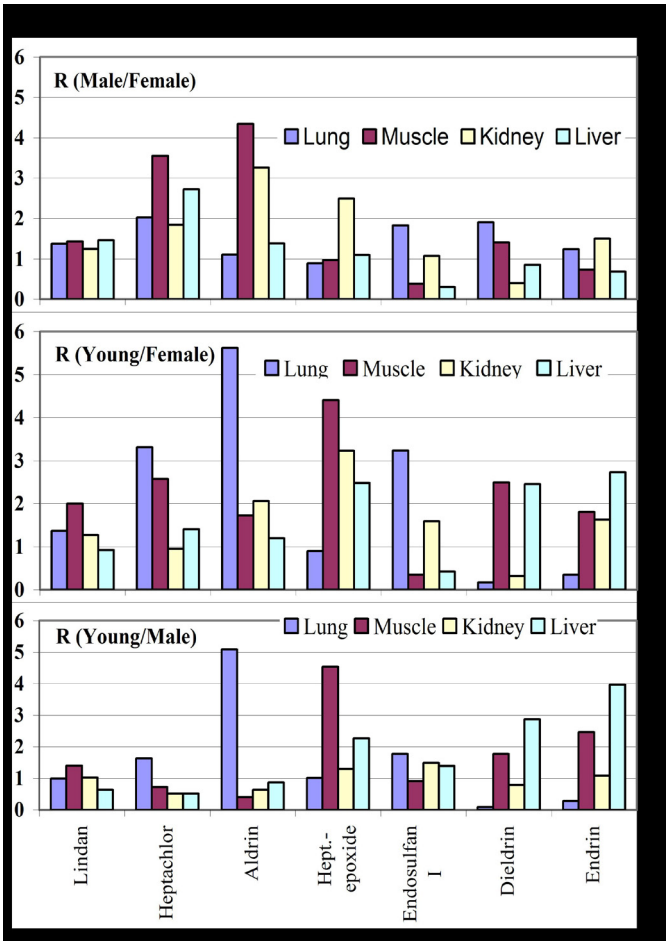


Figure 2. Average ratios of pesticides concentration in different tissues and organs between male and female (M/F), young and female (Y/F) and young and male (Y/M) for *Stenellas coeruleoalba*.

Table 2. Mean concentration, Standard Deviation (S.D.) and number of individual (n) for young, male and female *Stenella coeruleoalba*

| | Young Range | Mean | S.D. | n | Male Range | Mean | S.D | n | Female Range | Mean | S.D | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lindan** | 7.0 - 19.6 | 14.1 | 5.2 | 4 | 5.1-23.3 | 13.5 | 5 | 13 | 3.2- 60.1 | 22.3 | 19.6 | 8 |
| **Heptachlor** | 2.8 - 11.1 | 6.6 | 3.7 | 4 | 1.9-17.1 | 6.8 | 4.6 | 13 | 1.7-12.7 | 5.9 | 3.7 | 8 |
| **Aldrin** | 3.2 - 31.3 | 16.2 | 10.1 | 4 | 1.5-29.7 | 10.9 | 7.8 | 13 | 3.2-31.0 | 10.9 | 8.7 | 8 |
| **Hept.-epoxide** | 14.0 - 226.1 | 177.1 | 159.6 | 4 | 21.3-100.8 | 56.8 | 60 | 13 | 4.8-416.5 | 74.1 | 116.8 | 8 |
| **Endosulfan I** | 4.6 - 71.0 | 55.5 | 52.2 | 4 | 12.9-72.9 | 38.5 | 21.4 | 13 | 11.8-102.7 | 56.1 | 36.3 | 7 |
| **Dieldrin** | 17.6 - 756.0 | 232.1 | 303.7 | 4 | 4.8-537.6 | 178.1 | 196.7 | 13 | 9.3-1254.8 | 356.6 | 464.7 | 8 |
| **Endrin** | 10.7 - 553.7 | 174.8 | 219.9 | 4 | 30.4-644.2 | 193.2 | 181.5 | 13 | 6.1-763.1 | 336.3 | 382.9 | 8 |

Table 3. Mean concentration, Standard Deviation (S.D.) and number of individual (n) for pesticides in organs other than blubber, for young, male and female *Stenella coeruleoalba*

| | | Young Range | Mean | S.D. | n | Male Range | Mean | S.D | n | Female Range | Mean | S.D | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Lindan** | 4.9-37.0 | 16.1 | 14.8 | 3 | 4.8-33.6 | 16.2 | 8.6 | 11 | 3.1-50.8 | 11.8 | 14.9 | 8 |
| | **Heptachlor** | 0.6-24.4 | 9.3 | 10.7 | 3 | 0.9-15.2 | 5.7 | 4.8 | 11 | 0.8-2.7 | 2.8 | 2 | 6 |
| | **Aldrin** | 0.4-80.1 | 40.3 | 39.9 | 2 | 0.8-20.8 | 7.9 | 6.7 | 10 | 1.0-19.1 | 7.2 | 7.5 | 8 |
| **Lung** | **Hept.-epoxide** | 3.9-45.0 | 12.9 | 18.6 | 3 | 3.0- 46.0 | 12.8 | 15.4 | 11 | 4.8-125.1 | 14.4 | 32.3 | 7 |
| | **Endosulfan I** | 42.3-82.8 | 62.6 | 20.3 | 2 | 3.0-147.0 | 35.3 | 47.6 | 8 | 2.6-76.7 | 19.3 | 24.9 | 7 |
| | **Dieldrin** | 1.87-7.64 | 3.9 | 2.6 | 3 | 1.6-147.4 | 43.6 | 43.5 | 11 | 3.4-51.6 | 22.9 | 19.4 | 8 |
| | **Endrin** | 12.4-18.1 | 15.3 | 2.9 | 3 | 22.1-161.9 | 54.3 | 44.9 | 10 | 11.9-166.9 | 44.1 | 47.5 | 8 |
| | | | | | | | | | | | | | |
| | **Lindan** | 4.9-35.8 | 15 | 12.1 | 4 | 5.6-31.5 | 10.8 | 8.4 | 10 | 1.1-37.0 | 7.5 | 9.6 | 11 |
| | **Heptachlor** | 3.0-8.5 | 6.3 | 2.1 | 4 | 0.5-33.4 | 8.7 | 101 | 8 | 0.5-6.4 | 2.4 | 1.9 | 8 |
| | **Aldrin** | 3.4-12.4 | 5.8 | 3.8 | 4 | 0.4- 84.5 | 14.5 | 25.3 | 11 | 0.5-7.7 | 3.3 | 2.8 | 8 |
| **Muscle** | **Hept.-epoxide** | 10.8-56.2 | 33.4 | 18 | 4 | 2.6-59;5 | 7.4 | 13.5 | 9 | 1.0-8.0 | 7.6 | 9.2 | 11 |
| | **Endosulfan I** | 3.5-32.0 | 15.7 | 12 | 3 | 1.0-41.3 | 17.3 | 16.5 | 9 | 1.2-237.9 | 45.1 | 74.4 | 9 |
| | **Dieldrin** | 4.0-449.4 | 124.7 | 187.7 | 4 | 4.1-304.1 | 70.3 | 87.7 | 10 | 3.0-128.8 | 50 | 58.1 | 11 |
| | **Endrin** | 16.5-236.7 | 106 | 94.5 | 3 | 6.4-144.4 | 43.1 | 38.6 | 12 | 2.7-217.7 | 58.7 | 60.9 | 11 |
| | | | | | | | | | | | | | |
| | **Lindan** | 10.4-28.3 | 17.9 | 7.6 | 3 | 6;1-29.5 | 17.4 | 7.5 | 15 | 2.5-38.3 | 14.1 | 12.2 | 12 |
| | **Heptachlor** | 0.5-7.4 | 2.8 | 3.2 | 3 | 1.7-14.0 | 5.5 | 4 | 16 | 0.7-5.2 | 3 | 1.4 | 10 |
| | **Aldrin** | 1.6-26.3 | 10.1 | 11.5 | 3 | 1.6 -118.3 | 15.9 | 27.6 | 16 | 1.6-14.0 | 4.9 | 3.7 | 11 |
| **Kidney** | **Hept.-epoxide** | 8.0-73.5 | 38.5 | 26.9 | 3 | 6.0-224.0 | 29.7 | 48 | 15 | 4.0-38.0 | 11.9 | 9.5 | 12 |
| | **Endosulfan I** | 4.7-147.8 | 54.2 | 66.2 | 3 | 4.8-107.1 | 36.4 | 30.9 | 16 | 2.2-135.8 | 34.2 | 45.4 | 9 |
| | **Dieldrin** | 4.7-179.8 | 66.6 | 80.1 | 3 | 3.5-249.4 | 84.4 | 102.6 | 16 | 3.3-965.4 | 212.3 | 314.6 | 12 |
| | **Endrin** | 24.7-164.7 | 83.9 | 59.2 | 3 | 4.5-785.2 | 77.5 | 184.9 | 18 | 8.7-45.8 | 51.6 | 74.3 | 11 |
| | | | | | | | | | | | | | |
| | **Lindan** | 3.9-18.8 | 12.1 | 5.6 | 4 | 8.5-35.4 | 19.1 | 14.8 | 17 | 3.9-68.1 | 13.1 | 16.9 | 13 |
| | **Heptachlor** | 2.0-6.6 | 3.9 | 1.9 | 4 | 0.9-21.8 | 7.6 | 8 | 18 | 1.1-3.9 | 2.8 | 1 | 7 |
| | **Aldrin** | 0.1-26.9 | 9.2 | 10.7 | 4 | 0.4-36.3 | 10.7 | 10.9 | 18 | 1.8 -21.1 | 7.7 | 7 | 10 |
| **Liver** | **Hept.-epoxide** | 15.7-158.9 | 75.6 | 58 | 4 | 4.4 -166.7 | 33.4 | 42.5 | 16 | 3.0-214.7 | 30.5 | 54.7 | 13 |
| | **Endosulfan I** | 5.4-53.9 | 31.6 | 20 | 3 | 3.0-47.4 | 22.7 | 25.5 | 17 | 1.4-535.2 | 75.7 | 152.4 | 11 |
| | **Dieldrin** | 2.3-681.2 | 193.5 | 282.9 | 3 | 2.1-545.8 | 67.2 | 122.3 | 17 | 3.1-406.0 | 78.8 | 123.4 | 13 |
| | **Endrin** | 13.5-467.9 | 151 | 185.6 | 4 | 8.1-171.9 | 38.1 | 39.8 | 16 | 17.9-98.6 | 55.4 | 31.1 | 12 |

It emerges that the ratios of the concentration between the males and the females $R_{(M/F)}$, with a few exceptions, are higher than or equal to 1, which shows, the tendency of a strong accumulation of organochlorinated compounds in males compared to females. The ratios of concentration between the young dolphins and the females $R_{(Y/F)}$ show globally the same trends, confirming the strong contamination of young dolphins in comparison to adult females. Exceptions can be noted concerning the endosulfan in the liver and the muscle, the dieldrin in the lung and the kidney and the endrin in the lung and the liver. Nothing helps explain the peculiarities observed. But in the marine environment, the kinetics of exposure to pollutants is variable from one organism to another and also depends on physico-chemical factors. Ratios of concentrations between young dolphins and the males, $R_{(Y/M)}$, seem broadly indicated that young ones would be more contaminated than the adults, but the trends are less sharp.

# Conclusion

In general, levels of organic compounds in the organs of dolphins are rather heterogeneous and may vary significantly from one individual to another. This heterogeneity may be in relationship with the nutrition conditions of the animals, their state of health, but also with the preservation state of the tissues. For the interpretation of results, we have chosen to reason on average values bearing in mind that standard deviations are often high. In all the samples studied, the pesticides as dieldrin and endrin are relatively high, on the other hand, the concentrations of the other pesticides are sometimes negligible.

In the same sample, the dieldrin, unless exception is often in high proportion compared with aldrin, reflecting certainly the presence of this compound in the medium since a long time.

By contrast, we have measured contents in endrin varying from 6 to 1,526 $ng.g^{-1}$, in blubber. These values are relatively high

compared to the former pesticides and are comparable to those obtained by Hensen *et al* (2004) respectively 582 to 1,101 ng.g$^{-1}$. All these data reflect the persistent nature of the organic compounds in the environment. Some of them, like lindane or dieldrin are particularly toxic for many aquatic species from the early stages of the life. In the marine organisms these recalcitrant compounds, associated with many other toxics compounds can lead to the suppression of immune defense (Jepson *et al* 2005), can affect reproduction (Wells *et al* 2005), and may even generate tumors (Martineau *et al* 1999).

Given our results and the information's available, it is difficult to assign to the pesticides the causes of death of the stranded dolphins but the levels of contaminants measured are likely to contribute significantly.

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