Characterization of organochlorine pesticides in the surface waters of Marchica Lagoon, Morocco

Sanae Kaddouri 1, *, Bouchra Oujidi 1, 4, Mohamed Kabriti 2, Hassan Ouahidi 2, Mostafa Layachi 3, Chourouq Laqsir 1, Rajaa Aitali 4, Mohamed Chahban 1, Mourad Baghour 1, Ali Skalli 1, Mohammed El Bouch 2, And Mustapha Akodad 1

1 Laboratory OLMAN-BPGE, Multidisciplinary Faculty of Nador, Mohamed First University, Oujda, Morocco
2 National Laboratory for Pollution Studies and Monitoring (LNESP), Rabat, Morocco
3 National Institute of Fisheries Research (INRH), Regional Centre Nador, Morocco
4 GEOPAC Research Center, Geophysics and Natural Hazards Laboratory, Scientific Institute, Mohamed V University, Rabat, Morocco

Abstract. The main objective of this initial study is to assess the extent of surface water contamination in Marchica Lagoon caused by organochlorine pesticides (OCPs) historically used in agriculture through a sampling network consisting of eight stations covering all areas of the lagoon during the 2022 summer season. Located on Morocco’s Mediterranean coast, the lagoon has undergone several restoration actions since 2010 to improve its environmental state. However, this ecosystem is under constant pressure from its watershed, which can convey water pollution from agricultural, industrial, mining, and domestic sources, making continuous monitoring essential. Eight organochlorine pesticides (Alpha HCH, Beta HCH, Gamma HCH, Aldrin, Dieldrin, DDD, DDE, and DDT) were detected by gas chromatography-mass spectrometry (GC-MS) using the SIM (Selected Ion Monitoring) method. The results revealed OCPs contamination of the lagoon’s surface waters; the spatial variation of total OCPs concentrations (Σ8OCP) ranged from 7.58 to 18.79 ng/l. The predominant element detected was β-HCH (lindane), recorded between the Bouarg channel and Selouane wadi, an area characterized by intensive agriculture.

1 Introduction

Organochlorine pesticides (OCPs) are a class of persistent organic pollutants (POPs) that have caused considerable concern due to their persistence, toxicity, bioaccumulation, and long-distance transport [1-3]. POPs are present in the aquatic environment from a wide variety of anthropogenic sources such as industrial, agricultural, and municipal effluents, atmospheric deposition, coastal activities, shipping, and accidental spills [4-6]. OCPs have been banned by the Stockholm Convention since 2001 and are listed as primary pollutant concerns [7-8].

Marchica Lagoon is a coastal lagoon in the Mediterranean basin, experiencing the impacts of its watershed. The agricultural sector represents one of the main activities around this lagoon and is characterized by the use of pesticides, which can negatively impact the lagoon [9-11]. The primary objective of this initial study is to assess the extent of surface water contamination in Marchica Lagoon by organochlorine pesticides following its ecological restoration after being previously impacted by long-term agricultural use of the surrounding areas.

2 Methodology

2.1 Study area

Marchica is the only lagoon ecosystem on Morocco’s Mediterranean coast. It covers an area of 115 km² and has a maximum depth of 8 meters. The coastal Marchica watershed is home to a population of more than 400,000 [9]. The lagoon has been classified as a Ramsar site since 2005. It is separated from the Mediterranean Sea by a 25 km sandbar. The area has a Mediterranean climate.

The main rivers flowing into Marchica Lagoon include the Akhandouk and Ouchen wadis in the city of Beni Ensar, the Selouane wadi in the city of Bouarg, the Cabaillo wadi in the city of Nador, and the Afelioun and Lhdara wadis in the city of Arekmane. Except for Selouane wadi, the flow of these wadis is limited to periods of high flooding, resulting in solid and liquid discharges into the lagoon [9]. The main socio-economic activities are related to artisanal fishing, agriculture, industry, tourism, and mining [12-13].
2.2 Sampling monitoring and analysis

Surface water samples (0.5 m) from Marchica Lagoon were collected during the dry season (July 2022). The sampling network consisted of eight stations characterizing potential sources of discharge from watercourses in the watershed. Water samples were collected in one-liter bottles, which had been rinsed with extraction solvent. Physico-chemical parameters (temperature, pH, dissolved oxygen, and turbidity) were recorded in situ.

Organochlorine pesticides (OCPs) dissolved in water were extracted using the liquid/liquid extraction technique with hexane. Subsequently, the two phases were separated using a separating funnel. The resulting extract, approximately 50 ml in volume, was then evaporated in a rotary evaporator to reduce its volume to approximately 10 ml, and treated sodium sulfate was added to the extract to remove any remaining water molecules. Following this, the extract underwent a purification process, and a stream of nitrogen was applied to reduce the volume further to 1 ml, resulting in the final extract.

![Study area and sampling stations in the Marchica lagoon during the dry season of 2022.](image)

3 Results and Discussion

The physico-chemical parameters (Table 1) showed that the temperature varied between 27.7 to 33.7 °C, with a mean value of 29.6. pH ranged from 7.4 to 8.6, with a mean value of 8.1. Dissolved oxygen ranged from 4.8 to 11.8 mg/l, with a mean value of 8 mg/l. Turbidity varied from 1.2 to 33.7 NTU, with a mean value of 12.3.

Sixteen organochlorine pesticides were analyzed; only eight compounds were detected in the lagoon and examined in this study (Fig. 1): Three hexachlorohexane isomers (Alpha HCH, Beta HCH, and Gamma HCH), Aldrin, Dieldrin, and three DDT isomers (DDD, DDE, and DDT). The distribution of OCPs detected showed a dominance of HCH (lindane) and DDT compounds. The spatial variation of total HCH (ΣHCH) showed that the highest value was recorded in the area between the Bouarg Channel and Selouane wadi (S6), characterized by intensive agriculture, and the most dominant element was β-HCH (Lindane). The spatial variation of total DDT (ΣDDT) indicates that the highest value was recorded in the area near the sandbar side Arekmane (S3). The spatial variation of Aldrin and Dieldrin showed that the highest values were recorded in the area of Beni Ensar (S1) and the wastewater treatment plant (S7), respectively. The spatial variation of total OCPs concentrations (ΣOCPs) in the lagoon ranged from 7.58 to 18.79 ng/l, with the highest value recorded in the area near the sandbar side Arekmane (S3).

<table>
<thead>
<tr>
<th>Marchica Lagoon</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>Dissolved Oxygen (mg/l)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>27.7</td>
<td>7.4</td>
<td>4.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Max</td>
<td>33.7</td>
<td>8.6</td>
<td>11.8</td>
<td>33.7</td>
</tr>
<tr>
<td>Mean</td>
<td>29.6</td>
<td>8.1</td>
<td>8</td>
<td>12.3</td>
</tr>
</tbody>
</table>

Table 1. Physico-chemical parameters of the surface water of Marchica Lagoon during the dry season of 2022.
The contamination of marine waters by OCPs has been mentioned by authors worldwide. The maximum concentration of $\sum 8$OCPs in our study was lower than that of $\sum 7$OCPs recorded in Oualidia Lagoon [14], the maximum concentration of $\sum$DDT was higher than that recorded in Bizerte Lagoon [15], and the dieldrin and aldrin concentrations were lower than those found in Lagos Lagoon [16].

Despite the existing regulatory framework, undesirable amounts of banned pesticides may still exist in the environment. HCHs and DDTs were used in agriculture and sanitation for disease and mosquito control, resulting in widespread environmental contamination [17]. HCHs have been found in most human populations studied, and $\beta$-HCH was the most prevalent HCH isomer [18]. The presence of DDT, its persistence as an insecticide, and its metabolites (DDE and DDD) remain major public health issues worldwide [19-20].

![Fig. 2. Organochlorine pesticides (ng/l) in the surface water of Marchica Lagoon during the dry season of 2022.](image)

4 Conclusion

Our results revealed the presence of eight organochlorine pesticides in the surface waters of Marchica Lagoon. The HCH and DDT groups were predominant at most of the monitored stations. The highest levels of contamination were recorded in the area between the outflow of Selouane wadi and the Bouarg Channel. It is recommended that pesticide monitoring be conducted throughout the different seasons, a pesticide management plan be established, and awareness-raising actions be carried out with farmers.

References


