Distribution and Sources of Organochlorine Pesticides in Sediments of Khor Al Zubair, NW Arabian Gulf

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Abstract

Organochlorine pesticides (OCPs) are known to be Persistent Organic Pollutants (POPs) which cause severe risks for the aquatic environment as well as human health due to their high lipophilic properties, resistance in the environment, and ability for bioaccumulation. The current research aims to examine the distribution, concentration, and probable sources of 14 OCPs in surface sediments in five stations in Khor Al Zubair – the main estuarine channel in Southern Iraq flowing into the northwestern Arabian Gulf. The total concentration of OCPs (ΣOCPs) varied from 0.701 ng/g in Station 5 to 1.185 ng/g in Station 1. Heptachlor epoxide (0.620 ng/g in Station 1) and aldrin (0.232 ng/g in Station 5) were the major OCPs found. The grain size of sediment was found to be dominated by the presence of fine-grained sediments (clay and silt), with total organic carbon (TOC) concentration being quite variable. The statistical analysis of three replicates showed reliable data with low standard deviation. When compared to the regional data on OCP concentration in sediment samples from Iran, Kuwait, Bahrain, and other Arabian Gulf countries (Table 4), it appears that the OCP concentration in Khor Al Zubair sediments is relatively high, which could be caused by continuing inputs from agriculture and historic application, as well as mobilization from polluted soils. The prevalence of degradation products (heptachlor epoxide, DDE) over their parent compounds speaks in favor of both historical application and long-range atmospheric transportation.

Keywords: Organochlorine pesticides, sediments, Khor Al-Zubair, Arabian Gulf, persistent organic pollutants, sediment contamination.

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Introduction

Organochlorine pesticides (OCPs) constitute a group of man-made organic chemicals that were extensively used in agricultural practices and public health vector control campaigns between the 1940s and the 1970s. These organochlorines, which are known for their chemical stability, lipophilic nature, and non-degradability in the environment, fall into the category of persistent organic pollutants (POPs) in the Stockholm Convention (UNEP, 2001). Although banned and regulated internationally in terms of manufacturing and usage, OCPs still persist in different environmental compartments all around the world, thanks to their persistent nature and ability to travel over long distances through the atmosphere (Jones and de Voogt, 1999; Wania and Mackay, 1996).

The Arabian Gulf is an almost enclosed marginal body of water that receives large amounts of pollutants from the neighboring industrialized and agriculturally developed areas. The north-western region of the Arabian Gulf, especially the region near the mouth of Shatt Al Arab River and Khor Al Zubair Channel in Southern Iraq, is highly contaminated because of the convergence of several polluting agents. The Tigris-Euphrates river system originates from the agricultural drainage basin wherein OCPs were used traditionally, carrying pesticides into the Mesopotamian marshes, Shatt Al Arab estuary, and finally into the Arabian Gulf (DouAbul *et al.*, 1988; Al Kayoon *et al.*, 2025).

Khor Al Zubair is a tidal channel found south of the city of Basrah that serves as a link between the Shatt Al Arab estuary and the Gulf's northwestern waters. This waterway is found in an area characterized by high agricultural production, oil prospecting activities, and industrial developments. This makes it an ideal location for examining the contamination of organic pollutants (Al Jidyawi *et al.*, 2025). Past research has reported on the contamination of sediments in the Khor Al Zubair channel with organochlorines, with PCB levels being from 0.01 to 2.22 ng/g dry weight (Al Jidyawi *et al.*, 2025).

Sediments are considered to be one of the most important sinks for hydrophobic organic contaminants like OCPs. The distribution and behavior of these substances in sediments can be influenced by various factors such as sediment particle size, TOC content, hydrodynamics, and distance from sources (Guo *et al.*, 2009). Sediments with fine particles and high TOC contents possess high sorption properties for hydrophobic substances that result in higher OCP levels in these deposits (Frontiers, 2024).

Goals of this study included: (1) Determination of concentrations of 14 OCPs in surface sediments of five stations in Khor Al-Zubair, (2) Characterisation of patterns of OCP distribution in terms of spatial variability as a function of sediment size fractions and TOC content, (3) Source identification of OCP contaminants using ratios of OCPs and their degradation products, and (4) Comparison of OCP concentrations with those reported from other places in Iran and Arabian Gulf region (Table 4).

Materials And Methods

Study Area and Sampling

Sediment surface samples were collected from five sites located at Khor Al Zubair channel in the south part of Iraq fig(1). These sample sites range between upstream sites, which are close to both industries and agriculture (Sites 1–2), to downstream sites that are close to the Gulf (Sites 4-5), Site 3 being in between. Sediment samples were collected in triplicates from each site by using a Van Veen grab.

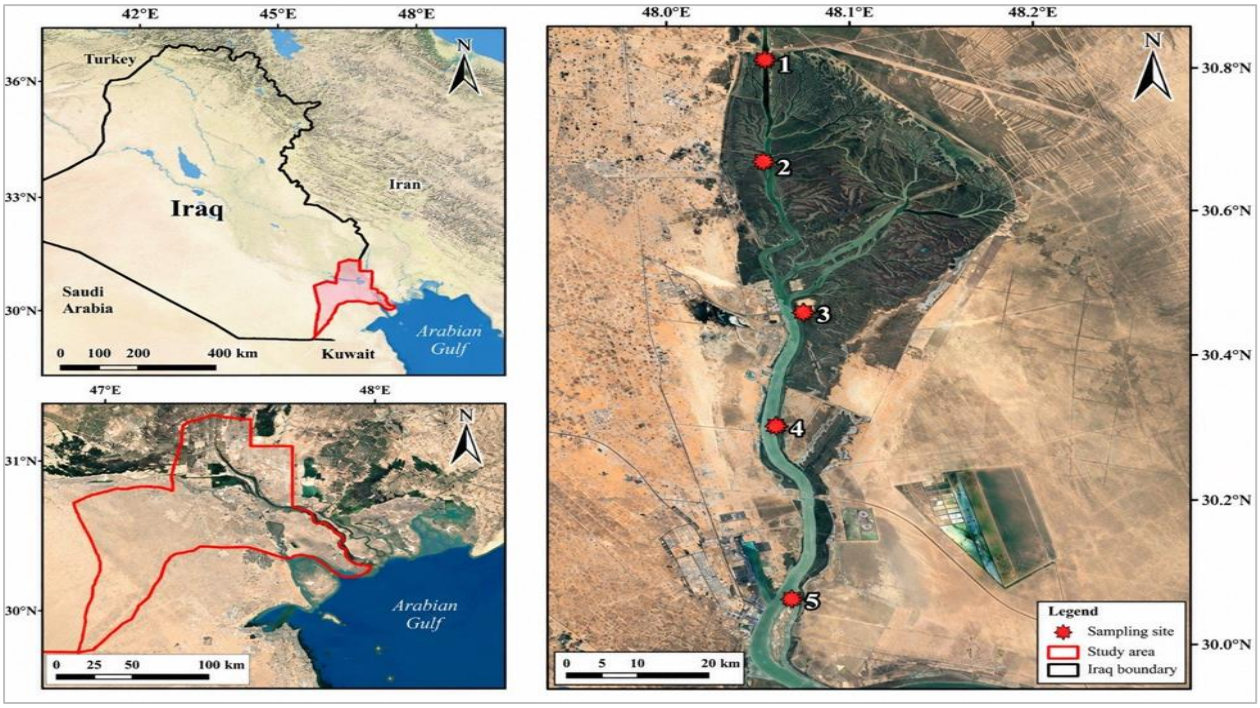

Figure 1: Map of the study area showing the five sampling stations in the Khor Al-Zubair.

Sample Analysis

Sediment samples were air-dried at room temperature, homogenized, ground using a clean mortar and pestle, and passed through an appropriate sieve before laboratory analysis. All results were calculated and expressed on a dry-weight basis. Total organic carbon (TOC) in the sediment samples was determined using the wet oxidation method described by Walkley and Black (1934). A known weight of dried sediment was oxidized with potassium dichromate ($K_2Cr_2O_7$)in the presence of concentrated sulfuric acid (H_2SO_4). After completion of the oxidation process, the remaining excess dichromate was determined by titration with ferrous ammonium sulfate using a suitable indicator. A reagent blank was analysed under the same conditions, and the TOC content was calculated and expressed as a percentage of sediment dry weight.

Particle-size distribution was determined using the combined sieving and pipette methods according to Folk (1974). A known weight of dried sediment was treated with a suitable dispersing agent to separate the aggregated particles. The sand fraction was separated from the finer fractions by wet sieving, whereas the silt and clay fractions were determined by the pipette method based on their differential settling velocities. The percentages of sand, silt, and clay were calculated relative to the total dry weight of the

sediment sample, and sediment texture was subsequently classified according to the proportions of these three fractions.

For the extraction of organochlorine pesticides, 50 g of dried and homogenized sediment was placed in a cellulose extraction thimble and extracted using a Soxhlet apparatus with 100 mL of n-hexane:dichloromethane (1:1, v/v) for 24 h at a temperature not exceeding 50°C, according to USEPA Method 3540C (USEPA, 1996). Following extraction, the solvent extract was concentrated to a small volume using a rotary evaporator. The concentrated extract was then purified through a chromatographic clean-up column containing activated Florisil and anhydrous sodium sulfate to remove moisture and co-extracted interfering substances. The cleaned extract was further concentrated to a known final volume under a gentle stream of nitrogen and transferred into clean amber glass vials until instrumental analysis.

The separation, identification, and quantification of the organochlorine pesticide compounds were performed by gas chromatography according to USEPA Method 8081B (USEPA, 2007). Compounds were identified by comparing their retention times with those of certified reference standards, while their concentrations were calculated using the corresponding calibration curves. The concentrations of the detected compounds were expressed as ng g^{-1} dry weight.

Sediment samples were analysed for 14 organochlorine pesticide compounds: α-HCH, γ-HCH (lindane), δ-HCH, heptachlor, aldrin, heptachlor epoxide, DDE, dieldrin, DDD, endrin aldehyde, endrin ketone, methoxychlor, endrin, and endosulfan. The sum of organochlorine pesticides (ΣOCPs) was calculated as the total concentration of these 14 compounds in each sediment sample at each station.

All sediment samples were analysed in replicate. Statistical parameters, including the mean, standard deviation, standard error, minimum, maximum, and range, were calculated from the repeated measurements.

Results

Organochlorine Pesticide Concentrations

The concentrations of 14 OCP compounds at the five study stations are presented in Table 1. Total OCP concentrations (ΣOCPs) ranged from 0.701 ng/g at Station 5 to 1.185 ng/g at Station 1, with intermediate values of 0.776 ng/g at Station 2, 0.964 ng/g at Station 3, and 0.803 ng/g at Station 4.

Table 1: Organochlorine Pesticide Concentrations at Study Stations (ng/g dry weight).

Compounds	Station (1)	Station (2)	Station (3)	Station (4)	Station (5)
α-HCH	0.023	0.053	0.031	0.028	0.022
γ-HCH (Lindane)	0.017	0.031	0.025	0.016	0.016

Compounds	Station (1)	Station (2)	Station (3)	Station (4)	Station (5)
δ-HCH	0.035	0.042	0.023	0.030	0.028
Heptachlor	0.028	0.062	0.028	0.026	0.010
Aldrin	0.140	0.054	0.140	0.121	0.232
Heptachlor epoxide	0.620	0.052	0.282	0.252	0.017
DDE	0.010	0.010	0.030	0.018	0.028
Dieldrin	0.028	0.201	0.032	0.021	0.042
DDD	0.021	0.090	0.035	0.030	0.027
Endrin aldehyde	0.042	0.061	0.128	0.063	0.044
Endrin ketone	0.131	0.010	0.135	0.131	0.132
Methoxychlor	0.030	0.042	0.023	0.019	0.018
Endrin	0.014	0.040	0.027	0.016	0.060
Endosulfan	0.046	0.028	0.025	0.032	0.025
ΣOCPs	1.185	0.776	0.964	0.803	0.701

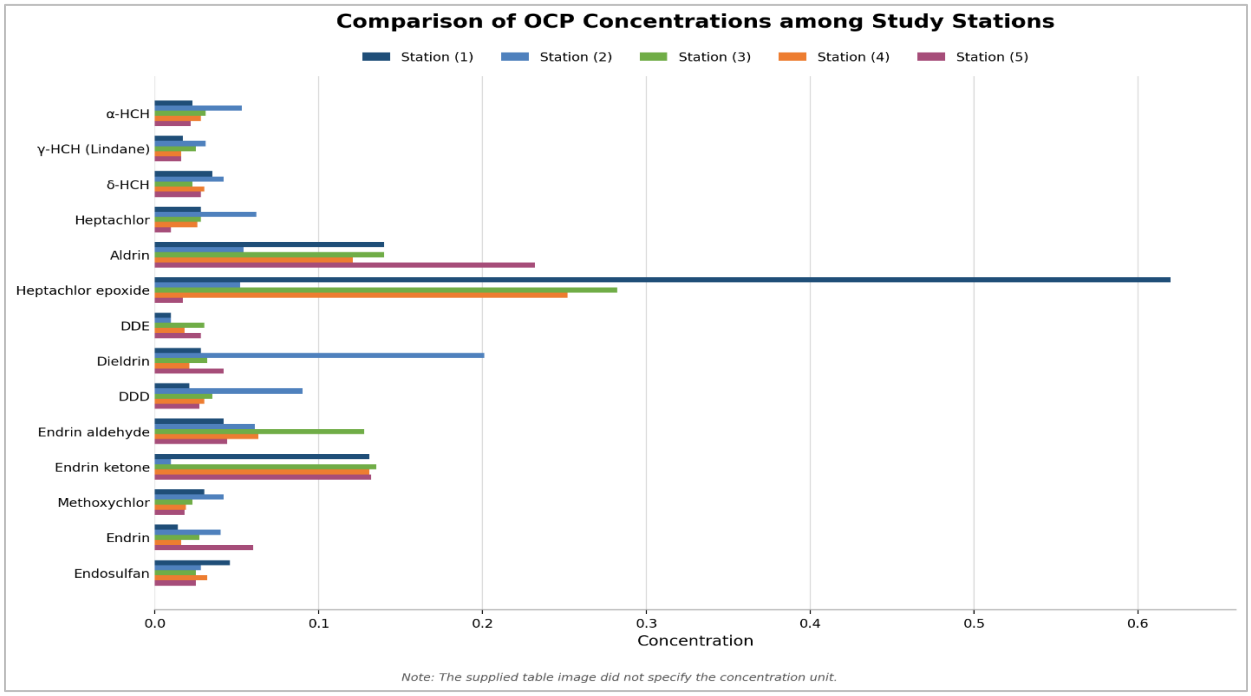

Figure 2: comparison of opc concetration among study station.

Among individual compounds, heptachlor epoxide exhibited the highest concentration at Station 1 (0.620 ng/g), followed by aldrin at Station 5 (0.232 ng/g) and endrin ketone at Station 5 (0.132 ng/g). Dieldrin showed elevated concentrations at Station 2 (0.201 ng/g) compared to other locations. The HCH isomers (α-, γ-, δ-) were present at relatively low concentrations across all stations, ranging from 0.016 to 0.053 ng/g.

Statistical Summary of Replicate Measurements

Replicate analyses were done at each site to evaluate the precision of the analysis (Table 2 and figure 3). The mean values varied between 0.055 ng/g at Station 3 and 0.203 ng/g at Station 5, with standard deviations of 0.003 to 0.018, respectively.

Table 2: Statistical Summary of Replicate Measurements (TOC)

location	DATA	RANG	MEAN	SD	SE
Station 1	0.140, 0.132, 0.152	0.132-0.152	0.141	0.010	0.006
Station 2	0.130, 0.128, 0.134	0.128-0.134	0.130	0.003	0.002
Station 3	0.067, 0.034, 0.063	0.063-0.067	0.055	0.018	0.010
Station 4	0.164, 0.159, 0.162	0.159-0.164	0.161	0.003	0.001
Station 5	0.201, 0.198, 0.211	0.198-0.211	0.203	0.007	0.004

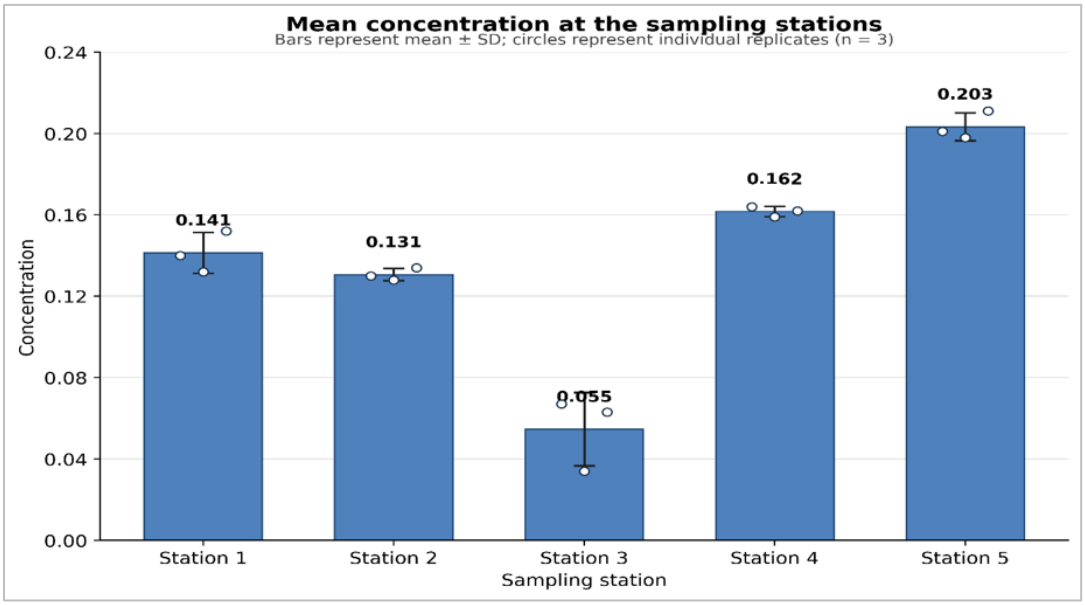

Figure 3: mean concentration at the sampling stations.

Total Organic Carbon and Grain Size Distribution

TOC concentrations differed significantly from one station to another (Table 2). High TOC levels were recorded in stations having high proportion of fine sediments which corroborates well with the established ability of organic materials to adhere on fine sediments. In terms of grain sizes, there were great variations in the texture of the

sediments (Table 3 and fig 4). Station 1 was composed mainly of sandy sediments (70.14% sand) while Stations 2, 4, and 5 had high percentages of clays (68.22%, 50.86%, and 59.68% clay, respectively). Station 3 had relatively equal proportions of sand (24.56%), silt (35.64%) and clay (39.80%).

Table 3: Grain Size Analysis at Each Station (%)

LOCATION	SAND	SILT	CLAY
STATION 1	70.14	5.82	24.04
STATION2	8.93	22.85	68.22
STATION 3	24.56	35.64	39.80
STATION 4	20.51	28.63	50.86
STATION 5	0.20	40.12	59.68

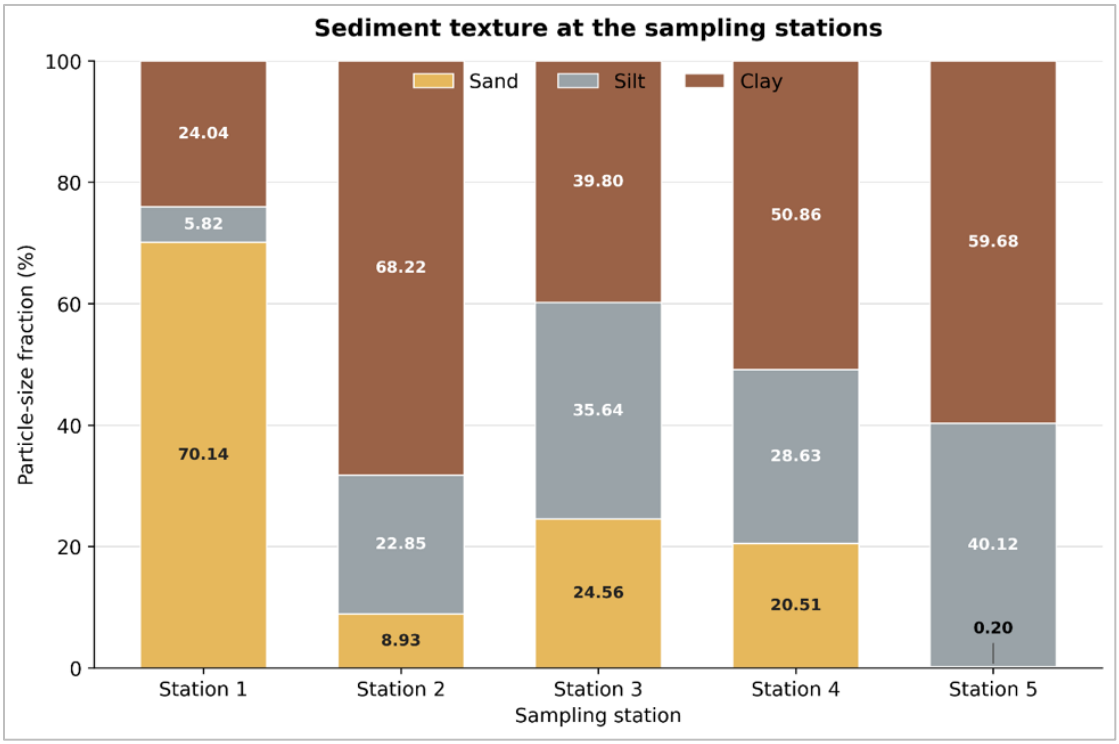

Figure 4: sediment texture at the sampling stations.

Discussion

Spatial Distribution of OCPs

The distribution of ΣOCPs in Khor Al Zubair is characterized by a decreasing gradient starting from the upstream locations (Station 1: 1.185 ng/g) to the downstream end of the

channel (Station 5: 0.701 ng/g), with few exceptions at intermediate stations (2-4). These results indicate that the major sources of OCP pollution are upstream, which can be attributed to agricultural drainage from the Tigris Euphrates Basin and discharge of contaminated water from Basrah industries. It has been found that Shatt Al Arab estuary serves as a major route of OCP transport from agricultural regions to the Gulf (Al Kayoon *et al.*, 2025).

The high values of the total ΣOCPs found at Station 1 (1.185 ng/g) could be a result of the influence that this station is exposed to in close proximity to industries and urban settings within Basrah city, as well as its status as the primary sedimentation site for contaminants carried downstream. Studies conducted on the Khor Al Zubair channel have shown the levels of PCBs to range between 0.01 – 2.22 ng/g (Al Jidyawi *et al.*, 2025).

Influence of Sediment Characteristics on OCP Distribution

Sediment grain size and TOC with respect to OCP levels are important determinants of the patterns of contaminants. Hydrophobic organic chemicals like OCPs are known to bind selectively to sediments that are fine-grained and rich in organic carbon because of their hydrophobic nature (Frontiers, 2024). However, in the current study, the highest value of ΣOCPs in sediments at Station 1 (1.185 ng/g) was observed in sediments with the highest percentage of sand (70.14%) and lowest amount of silt (5.82%), which seems contradictory to the usual notion that finer sediments tend to contain higher levels of contaminants. Nevertheless, it is noteworthy that Station 1 also has the highest amount of heptachlor epoxide (0.620 ng/g), which is a major constituent of ΣOCPs in this station. On the other hand, stations 2, 4, and 5, composed of clay-dominated sediments (68.22%, 50.86%, and 59.68% clay, respectively), exhibited moderate to low ΣOCPs (0.776, 0.803, and 0.701 ng/g, respectively). The relatively lower concentration of these fines could be attributed to dilution effects or the fact that these fine-grained sediments are far from any source. Station 3, having an intermediate grain size composition, had ΣOCPs of 0.964 ng/g, implying that other factors apart from grain size could play an important role in the distribution of OCPs. It is common to observe positive correlations between the concentrations of OCPs and the percentage of fine-grained sediments (silt and clay) in other studies, with hydrophobic OCPs being preferentially absorbed by fine particles (Frontiers, 2024). Nevertheless, the dynamic nature of the Khor Al Zubair channel because of its tidal flushing effects and Shatt Al Arab discharges makes this assumption complicated.

Compound-Specific Patterns and Source Identification

Heptachlor epoxide was dominant at Station 1 (0.620 ng/g) and found at other stations in concentrations of (0.017 – 0.282 ng/g). It should be mentioned that heptachlor epoxide is the metabolite of heptachlor, which is OCP. Heptachlor was extensively used for agricultural purposes and as a termite pesticide. Presence of heptachlor epoxide at all stations and at higher concentrations compared to its parent compound suggests that it has been previously used in the area and transformed to heptachlor epoxide in the

environment. In previous studies conducted in Khor Al Zubair, the concentrations of heptachlor were reported to be 0.01-0.06 ng/kg in surface sediments (DouAbul *et al.*, 2009). The occurrence of high amounts of aldrin (0.140-0.232 ng/g) along with its degradation product dieldrin (0.021-0.201 ng/g) is yet another proof of OCP usage. It is known that the process of converting aldrin to dieldrin occurs quickly due to epoxidation and the aldrin to dieldrin ratio can talk about the freshness of the input materials. Comparing the higher amount of aldrin to dieldrin at the stations 1, 3, 4, and 5 and the high amount of dieldrin at station 2 (0.201 ng/g vs 0.054 ng/g aldrin), it can be seen that there is a variation in degradation rate and/or inputs. The transformation of aldrin to dieldrin has been described before for the delta region of Tigris Euphrates Shatt Al Arab (DouAbul *et al.*, 2009).

All the three forms (DDT and its metabolites-DDE, DDD) were found at all sampling sites, where DDE (0.010-0.030 ng/g) and DDD (0.021-0.090 ng/g) were found at concentrations greater than DDT, which was not detected as a parent compound in this study. Presence of more amounts of DDE and DDD compared to DDT indicates that the pollution by these compounds occurred due to previous input of DDT followed by degradation, since DDT is degraded into DDE under aerobic conditions and into DDD under anaerobic conditions. Presence of DDT degradation products in all the samples is an indication of ban on the usage of DDT in Iraq and therefore, the contamination is due to historical input or input from distant regions through atmospheric transport (DouAbul *et al.*, 2009). Higher percentage of DDTs (~40%) in the sediment from Kuwait coast has been reported (Ali *et al.*, 2015). The detection of endrin and its metabolites (endrin aldehyde and endrin ketone) in all stations with very high levels of endrin ketone (0.010-0.135 ng/g) was observed. Endrin is an extremely toxic cyclodiene insecticide which has been banned for many years in almost all countries. The presence of endrin related compounds in the sediments of Khor Al-Zubair demonstrates their environmental stability.

Comparison with Regional Studies–A Quantitative Overview

To contextualise the OCP concentrations observed in Khor Al-Zubair sediments, we compared our results with published data from other locations in the Arabian Gulf and Iran. Table 5 summarises the available information on OCP levels in sediments from the region. As is evident from Table 5, the concentrations of ΣOCP in Khor Al Zubair (701-1,185 ng/g) are far higher than those observed in Kuwait (~5 ng/g for DDTs), Bahrain (generally low), and the UAE (not detectable). The only available comparable local data, from the same region, are the heptachlor residues from Shatt Al Arab Marshes (DouAbul *et al.*, 2009), which were of the ng/g order, some three orders of magnitude lower than the heptachlor epoxide concentrations recorded in the current study at Station 1 (620 ng/g). This difference implies that either the sampling sites vary in their distance from the source, or the inputs have increased over time due to remobilization of contaminated soils or illegal usage.

Table 5: Comparison of OCP Concentrations in Sediments from the Arabian Gulf and Iran

Location	Matrix	Compounds analysed	Concentration (range or mean)	Reference
Khor Al-Zubair, Iraq	Surface sediment	Σ14 OCPs (α-HCH, γ-HCH, δ-HCH, heptachlor, aldrin, heptachlor epoxide, DDE, dieldrin, DDD, endrin aldehyde, endrin ketone, methoxychlor, endrin, endosulfan)	701 – 1,185 ng/g (0.701–1.185 ng/g)	This study
Kuwait coast	Surface sediment	DDTs (sum of DDT, DDE, DDD)	~5 ng/g	Ali *et al.*, 2015
Kuwait coast	Surface sediment	PCBs (sum of 21 congeners)	22.7 ng/g	Ali *et al.*, 2015
Bahrain (national baseline)	Surface sediment	OCPs (including DDTs, HCHs, chlordanes)	Generally low; most compounds below detection or well below sediment quality guidelines	Bersuder *et al.*, 2020
UAE (northern Arabian Gulf coast)	Surface sediment	OCPs (DDTs, HCHs, etc.)	Not detectable (below LOD)	Samara *et al.*, 2023
Arvand Rood River, Iran	Surface sediment	Endosulfan (α and β), lindane (γ-HCH)	Detected; quantitative values not reported	Zare-Maivan *et al.*, 2011
ROPME Sea Area (regional survey)	Coastal sediments	Various OCPs	Low; no extensive contamination observed	ROPME, 2005
Shatt Al-Arab marshes, Iraq	Surface sediment	Heptachlor	0.01 – 0.06 ng/kg (0.01–0.06 ng/g)	DouAbul *et al.*, 2009

Note: Concentrations are expressed on a dry weight basis. LOD = limit of detection.

Despite the fact that the Iranian study conducted in the Arvand Rood (Zare Maivan *et al.*, 2011) identified endosulfan and lindane without quantifying the concentration range, a comparison on this basis is not possible. However, the identification of these chemicals in the water body that discharges its water into the northern Gulf suggests that contamination across boundaries is a regional phenomenon. According to the ROPME

regional survey (2005), there were no extensive instances of pollution in the Gulf; however, some hotspots can be identified in Khor Al Zubair.

The high values recorded in the current study compared to other areas in the Gulf region confirm the significance of the Tigris-Euphrates-Shatt Al-Arab system as an important route of transport of OCPs. Sediments containing residual pesticides have been found in the Mesopotamian Marshes area (DouAbul *et al.*, 1988). Such sediments can become resuspended in the water body and transported to Khor Al-Zubair and the Gulf waters. This is consistent with the results obtained at Station 1 (upstream).

Environmental Implications and Risk Assessment

The concentrations found for OCP in the sediments of Khor Al Zubair pose an ecological and human risk. Even though there are challenges in making a comparison with sediment quality guidelines due to the differences in methods used and compounds assessed, there are some compounds (such as heptachlor epoxide with 0.620 ng/g and aldrin with 0.232 ng/g) that have concentrations above the values found in un-contaminated sediments.

The fact that OCP accumulates in sediments puts benthic organisms at the risk of being exposed to it directly and other trophic levels at risk because of biomagnification and bioaccumulation. Research carried out in north-western Arabian Gulf has shown accumulation of DDT in fish and bivalve species with biota sediment accumulation factors confirming this transfer of pollutants from sediments to biota (Ali *et al.*, 2015). This means that the OCP present in Khor Al Zubair sediments can pose a risk to commercial fish and shellfish. Moreover, the possibility of resuspension and transportation of OCPs to the wider open areas of the Arabian Gulf is a source of contamination that needs to be considered. Tidal forces in the Shatt Al Arab Estuary increase the likelihood of retaining and redepositing the particle bound OCPs (Al Kayoon *et al.*, 2025).

Study Limitations and Future Research

Some of the limitations of this study should also be noted. First, the relatively small sample size (five stations with three times measured data) provides only partial insight into the distribution pattern of the OCPs. Second, the lack of information about the hydrologic and sedimentological characteristics of the sites makes it hard to explain the patterns in detail. Third, the lack of compound specific isotopic analysis or other source apportionment methods limits the capability of the source identification.

For future studies, the following aspects should be considered: (1) increase of the number of sampling stations along the Shatt Al Arab and surrounding Gulf area; (2) seasonal sampling of the sediments for better understanding of the temporal distribution patterns; (3) analysis of the sediment cores for tracing the historical pattern of OCP deposition; (4) use of molecular markers and isotopic analyses for better source identification; and (5) assessment of the bioavailability of OCPs in this area.

Conclusions

This paper offers the first complete evaluation of 14 organochlorine pesticides in surface sediments of the Khor Al Zubair channel of southern Iraq. The important findings are as follows:

The total concentration of OCPs was found to be between 0.701 to 1.185 ng/g, with the maximum concentration being recorded at Station 1, indicating inputs from agricultural and industrial sources in the Tigris Euphrates basin.

Heptachlor epoxide, aldrin, and endrin ketone were the major components, thus indicating that cyclodiene pesticides were once used.

Presence of DDT transformation products, i.e., DDE and DDD, in all sediment samples, while there was no presence of parent DDT in any of the samples.

The comparison of the current results with regional studies in Kuwait, Bahrain, Iran, and UAE (Table 5) indicates that the levels of OCP in sediments of Khor Al Zubair are higher than those of other sites in Arabian Gulf. This means that the studied site is possibly a regional pollution hot spot.

Several factors affecting the distribution pattern of OCP in sediments include sediment grain size and total organic carbon, but the local contribution and hydrodynamics can be equally important.

High persistence of OCP in sediments of Khor Al Zubair may have adverse impacts on ecology and calls for further investigation of persistent organic pollution in the Mesopotamian marsh estuarine Gulf continuum.

The findings of this study contribute to the growing body of knowledge on OCP contamination in the Arabian Gulf region and provide a baseline for future monitoring and assessment efforts. Given the persistence and toxicity of these compounds, ongoing surveillance and source control measures are essential to protect the health of aquatic ecosystems and human communities that depend on them.

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توزيع ومصادر مبيدات الآفات الكلورية العضوية في رواسب خور الزبير، شمال غرب الخليج العربي

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المستخلص

تُعد المبيدات الحشرية الكلورية العضوية (OCPs) ملوثات عضوية ثابتة تشكل مخاطر جسيمة على النظم البيئية المائية وصحة الإنسان، وذلك نظراً لخصائصها المتمثلة في قابليتها العالية للذوبان في الدهون، وثباتها البيئي، وقدرتها على التراكم الحيوي. تناولت هذه الدراسة بحث توزيع وتركيزات ومصادر محتملة لـ 14 مركباً من مركبات المبيدات الكلورية العضوية في الرواسب السطحية التي جُمعت من خمس محطات على طول خور الزبير، وهو قناة مصبّ رئيسية في جنوب العراق تصب مياهها في الجزء الشمالي الغربي من الخليج العربي. تراوحت التركيزات الكلية لهذه المبيدات (ΣOCPs) بين 0.701 ميكروغرام/غرام في المحطة 5 و1.185 ميكروغرام/غرام في المحطة 1، حيث كان مركبا "هيبتاكلور إيبوكسيد" (0.620 ميكروغرام/غرام في المحطة 1) و"ألدرين" (0.232 ميكروغرام/غرام في المحطة 5) هما المركبين الأكثر وفرة. وأظهر تحليل حجم حبيبات الرواسب هيمنة الرواسب دقيقة الحبيبات (الطين والغرين) في معظم المحطات، مع تفاوت ملحوظ في محتوى الكربون العضوي الكلي (TOC) بين المواقع المختلفة. كما أظهر التحليل الإحصائي للقياسات المكررة ثلاثياً دقة عالية في تكرار النتائج مع انخفاض قيم الانحراف المعياري. وتشير المقارنة مع دراسات إقليمية أُجريت في إيران والكويت والبحرين ودول أخرى مطلة على الخليج العربي (الجدول 5) إلى أن مستويات المبيدات الكلورية العضوية في رواسب خور الزبير تُعد عموماً متوسطة إلى مرتفعة مقارنة بالمستويات الخلفية السائدة في المنطقة؛ مما يوحي بوجود مصادر مستمرة للتلوث ناتجة عن الجريان السطحي الزراعي، والاستخدامات التاريخية، واحتمالية إعادة تحرر الملوثات من التربة الملوثة. وتدل هيمنة نواتج التحلل مثل "هيبتاكلور إيبوكسيد" و"DDE" مقارنة بالمركبات الأصلية على كل من الاستخدام التاريخي للمبيدات وعمليات الانتقال الجوي لمسافات بعيدة. وتوفر هذه الدراسة بيانات مرجعية لبرامج الرصد المستقبلية، كما تسلط الضوء على الحاجة إلى استمرار مراقبة الملوثات العضوية الثابتة في النظام المتصل الممتد من أهوار بلاد الرافدين ومصباتها وصولاً إلى الخليج العربي.

الكلمات المفتاحية: مبيدات الآفات الكلورية العضوية، الرواسب، خور الزبير، الخليج العربي، الملوثات العضوية الثابتة، تلوث الرواسب.