Int. J. Environ. Res., 8(2):493-500,Spring 2014
ISSN: 1735-6865

Levels of Organochlorine Pesticide Residues in Water and Sediment from Selected Agricultural Sectors of Kanyakumari District, Tamil Nadu, India

Jeyakumar, T.[1*] , Kalaiarasi, I.[2] , Rajavel, A.[1] , Anbu, M.[3] and kumar, R.[4]

[1] Chemistry Section, Faculty of Engineering and Technology, Annamalai University,
Annamalainagar 608 002, Tamil Nadu, India

[2] Department of Physics, Annamalai University, Annamalainagar 608 002, Tamil Nadu, India

[3] Dioxin Research Section, National Institute for Interdisciplinary Science and Technology,
Thiruvananthapuram, Kerala, India

[4] Ministry of Environment and Forests, New Delhi 110 003, India

Received 27 July 2013; Revised 10 Dec. 2013; Accepted 20 Jan. 2014

ABSTRACT: The levels of 19 organochlorine pesticides (OCPs) in surface water and under water sediments from tanks located nearby the prime agricultural areas of Kanyakumari district, Tamil Nadu, India were investigated to evaluate their pollution risks. A total of 36 surface water samples at 9 sampling sites and 27 sediment samples at 9 sampling stations were collected from tanks, which were the water sources for cultivation. The total OCPs concentration in surface water and sediments were 5.68–25.12 ng/L and 17.7–58.59 ng/g dry weight (dw), respectively. Among the OCPs, hexachlorocyclohexanes (HCHs), dichlorodiphenyltrichloroethane (DDTs) and heptachlor epoxide were the most dominant compounds in the sediment as well as surface water. The dominant OCPs in sediment and water were β-HCH in HCHs, *p,p′*-DDD in DDTs and heptachlor epoxide in other OCPs. Distribution of HCHs, DDTs and other OCPs were different indicating their different sources. Composition analysis in sediments indicated a recent usage of lindane.

Key words: Organochlorine pesticides, Surface water, Sediment, HCHs, DDTs

INTRODUCTION

Organochlorine pesticides (OCPs) are one of the most important persistent organic pollutants (POPs) and have been of great concern around the world owing to their chronic toxicity, persistence and bioaccumulation (Willett *et al.*, 1998). These compounds pose great threats to ecosystems and human health. Although the application of these chemicals has been banned or restricted in many countries especially the developed ones, some developing countries are still using these compounds because of their low cost and versatility in industry agriculture and public health (Tanabe *et al.*, 1994; Pham *et al.*, 1996; Tkalin, 1996; Sarkar *et al.*, 1997). Through atmospheric long-range transport and water circulation, OCPs have distributed globally and are still detected in many aqueous environment from various regions (Walker *et al.*, 1999; Lee *et al.*, 2001; Fytianos *et al.*, 2006; Pandit *et al.*, 2006; Zhou *et al.*, 2006). Organochlorine pesticides (OCPs) such as hexachlorocyclohexanes (HCHs) and dichlorodiphenyltrichloroethane (DDTs) are of great concern around the world for their persistence in the environment, impact on nontarget organisms, and bioaccumulation in the tissues of animals as well as human via food chain (Willett *et al.*, 1998; Nakata *et al.*, 2002; Quan *et al.*, 2003; Chau, 2005).

In India although the residue levels of the organochlorine pesticides in the environments have considerably declined in the past 25 years, recent work has depicted that chlorinated pesticides could be detected in water and sediments of marine and estuarine environment (Sarkar and Sen Gupta, 1991; Sujatha *et al.*, 1993; Sujatha *et al.*, 1994; Sarkar *et al.*, 1997; Bhattacharya *et al.*, 2003; Guzzella *et al.*, 2005; Sankararamakrishnan *et al.*, 2005; Pandit *et al.*, 2006). The pesticides applied to the land eventually find their way to the aquatic environment thus contaminating them. These are transported to aquatic bodies by agricultural runoff, rain runoff, rivers and streams and associated with biotic and abiotic macroparticles (Colombo *et al.*, 1990). The study area Kanyakumari district is located in the southern part of the state of Tamil Nadu. In Tamil Nadu very few monitoring

---

*Corresponding author E-mail: jekeyg@yahoo.com

data is available for the presence of organochlorine pesticides in water and sediment (Ramesh *et al.*, 1991; Rajendran and Subramanian, 1997; Jeyakumar *et al.*, 2009). However, very few data on OCPs in agricultural sectors are available in Kanyakumari district. This prompted us to quantify and qualify the OCPs by gas chromatography-mass spectrometry (GC-MS) techniques.

The present study aims at assessing the occurrence of organochlorine pesticide like HCH isomers (α, β, γ and δ) DDT and its metabolites (DDD and DDE) and other OCPs in sediment and surface water form nine sampling stations, which are tanks nearby agricultural sectors.

MATERIALS & METHODS

The sampling region Kanyakumari district is located in the southern part of the state of Tamil Nadu and the southern most tip of peninsular India. It is located between 77°15′ and 77°36′ of east of longitudes and 8°03′ and 8°35′ north of latitudes, with an area of 1672 sq. km. The economy of this district is mainly based on agricultural activity. Paddy, coconut and banana are the main crops of this district. The locations of the sampling sites are shown in Fig. 1. The sites were chosen based on hotspots of pollution in the main agricultural sector of this region. All the sampling stations are small and shallow tanks, and are the main discharging station of agricultural runoff. The descriptions of each sampling site are as follows.

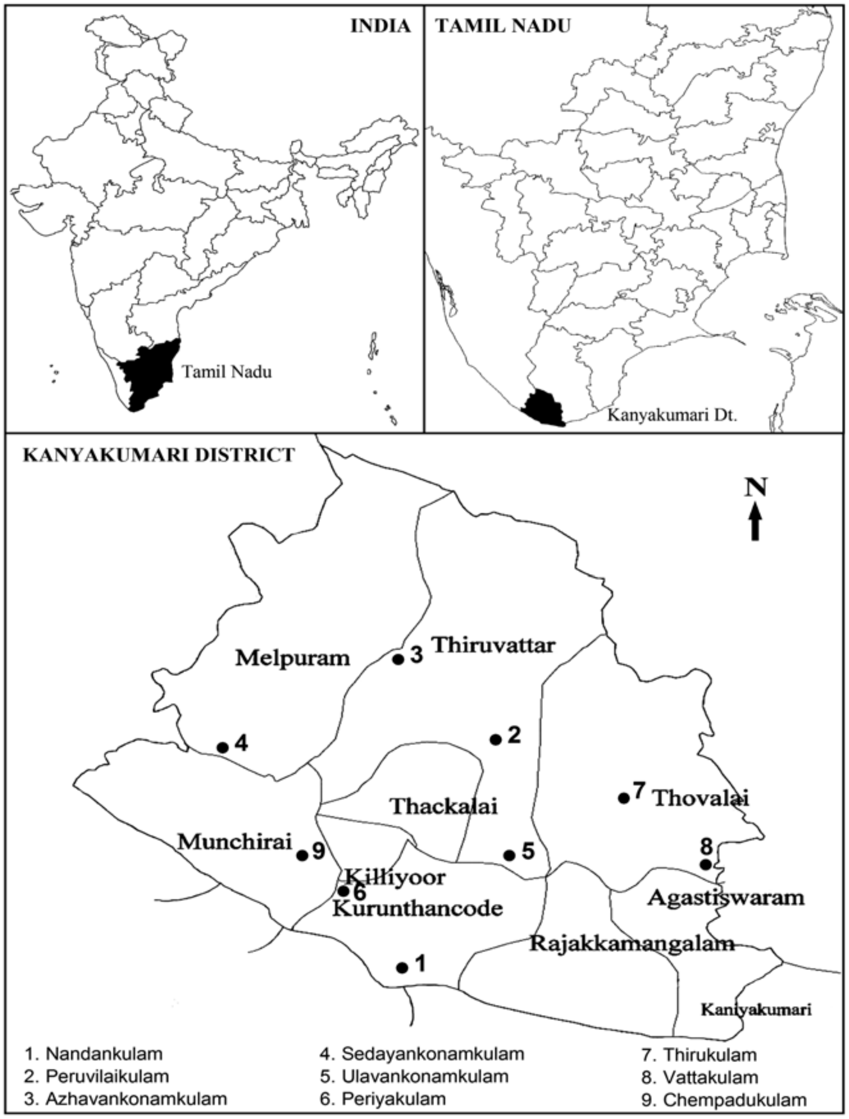

Fig.1. Map of Kanyakumari district showing location of sampling sites

Site S_1 (08°08′ N, 77°19′ E; Local name: Nandankulam) receives agricultural discharge from paddy field. Total area of the field is approximately 15 acre. Site S_2 (8°13′ N, 77°25′ E; Local name: Peruvilaikulam) is surrounded by paddy and banana field (13 acre) on all the sides of the tank, receives mainly agricultural discharges. Site S_3 (8°20′ N, 77°10′ E; Local name: Azhavankonamkulam) is surrounded by 10 acre of paddy and banana field and nearly 4 acre of vegetable forms. Site S_4 (8°16′ N, 77°10′ E; Local name: Sedayankonamkulam) is situated among an area of paddy and coconut field. The field covers totally of 20 acre. Site S_5 (8°09′ N, 77°24′ E; Local name: Ulavankonamkulam) is nearer to a small village and situated in middle of 15 acre area of paddy field alone. Site S_6 (8°11′ N, 77°16′ E; Local name: Periyakulam) which receives the discharge from paddy and banana field of nearly 17 acre. Site S_7 (8°10′ N, 77°27′ E; Local name: Thirukulam) is situated nearly a residential area and receives agricultural runoff from paddy field (10 acre) and coconut farm (5 acre). Site S_8 (8°10′ N, 77°34′ E; Local name: Vattakulam) is surrounded by paddy and banana field of area (20 acre). Site S_9 (8°11′ N, 77°14′ E; Local name: Chempadukulam) covers an area of 16 acre paddy and banana field and 7 acre of vegetable farm.

All the nine sampling stations are not having tail water pond. So the irrigation return flow reaches public water directly via canals. Hence the investigation is worthwhile. Global positioning system (GPS) was used to locate the sampling position. Sediment samples were collected from all the sampling stations using a stainless steel grab sampler. The top 5 cm layer of sediment was scooped using a precleaned stainless steel scoop into polythene containers. All the samples were placed on ice and transported to the laboratory, then frozen and stored at –20 °C until further analysis. Water samples were collected from 20 cm depth using grab water sampler (Cole-Palmer, India) and drained directly into a pre-rinsed 1 L amber glass bottle. The samples were kept at 4 °C until extraction.

All the nineteen pesticide standards were purchased from Accu Standards Inc. USA. All the pesticide standards were above 99% purity. Sodium sulphate anhydrous (Na_2SO_4), *n*-hexane, acetone, diethyl ether and dichloromethane and concentrated hydrochloric acid were obtained from Fisher Scientific, India. All the solvents were of chromatographic purity. Water samples were filtered with glass fiber filters 0.1 mm (Whatman, UK) to remove debris. The samples were extracted sequentially three times with 25 mL hexane each time. The extract was dried with anhydrous sodium sulphate and concentrated down to 10 mL by means of Kuderna Danish type concentrators. A clean up system, using a chromatographic column, packed with florisil, previously activated for 3 h in an oven at 130 °C and anhydrous sodium sulphate (all rinsed with petroleum ether) was used. The extract was transferred to the column. These fractions were obtained after elution with 6, 15, 50% ethyl ether in petroleum ether maximal flux rate of elution was 5 mL/min. The solvents used were all pesticide grade. Each elute was evaporated and the extracts were injected into a gas chromatographic system for identification and quantification of the pesticides.

The sediment was wet-sieved (63 μm) to separate the silt and clay fractions and subsequently air-dried and lightly ground in a mortar and pestle to breakup the aggregates. Five grams of sediment was extracted with 20 g of anhydrous sodium sulphate for 16 h in a Soxhlet apparatus with 200 mL of pesticide grade *n*-hexane:acetone (1:1 v/v). Then the extracts were evaporated to dryness in a speed-vacuum concentrator and fractioned by Florisil column chromatography and eluted with hexane as a first fraction, followed by 15% dichloromethane:hexane. All of the fractions were concentrated to a final volume of between 0.2 and 1 mL and were ready for analysis. The identification and quantification of organochlorine compounds was made by gas chromatograph, GC (Konik system 4000 series) equipped with Konik-Q12 model mass spectrometer (MS). A fused silica capillary column (HP-5, 30 m × 0.25 m i.d with 0.5 μm per film thickness) was used. The GC system was operated in a split less mode. 1 μL of each sample was injected. The temperature program during the run was as follows: 120 °C (2 min hold) to 180 C at a rate of 30 °C/min, to 200 °C (2 min hold) at 4 °C/min, to 240 °C (2 min hold) at 1 °C/min, and then to 270 °C at 2 °C/min with a final hold time of 10 min. Injector and detector temperatures were maintained at 250 and 300 °C, respectively. Helium (purity >99.99%) was employed as carrier gas at a flow rate of 2.32 mL/min. GC peaks were identified based on the retention time of individual authentic standards (±0.3%). The residues of OCPs were quantified by the external standard method.

RESULTS & DISCUSSION

Organochlorine pesticides (OCPs) including HCHs, DDTs, endrin, dieldrin and endosulphan are commonly used in agriculture. Once entering water bodies, these compounds will partition between sediments, water and biota. Although sediments may act as a reservoir for these contaminant, they can also release the contaminants back into the overlying water under certain conditions. The investigation of OCPs in sediments and water column is thus an important approach to assess the fate of these organic contaminants. Due to lack of information, there is a need to determine the occurrence and distribution of OCPs in the agricultural part of Kanyakumari district, and to evaluate the factors that influence their fate.

Concentrations of OCPs in sediments from the study area are shown in Table 1. Compounds identified included hexachlorocyclohexane (α-HCH, β-HCH, γ-HCH and δ-HCH), cyclodiene (aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, endosulphan I, endosulphan II and endosulphan sulphate), diphenyl aliphatic (*p,p′*-DDE, *p,p′*-DDD, *p,p′*-DDT, methoxychlor, heptachlor, heptachlor epoxide and chlordane). The total OCPs in sediments ranged from 17.7–58.59 ng/g dry weight, with a mean concentration of 32.7 ng/g. The highest concentration was found at station 3, coinciding with the highest concentration in water; this is therefore the most polluted location in the study area. High concentrations (>30 ng/g dry wt.) were also found at stations 2, 4, 5 and 6, which are close to paddy field and high density of banana field. The highest level of OCPs (58.6 ng/g) was found at site S_3 in Azhavankonamkulam and the lowest level (17.7 ng/g) was found at site S_7 in Thirukulam. The ubiquitous distribution of OCPs in sediments suggested an extensive use of these pesticides in the region.

Composition differences of HCH isomers or DDT congeners in the environment could indicate different contamination sources (Doong *et al.,* 2002a). Technical grade HCH consist principally of four isomers, α-HCH (60–70%), β-HCH (5–12%), γ-HCH (10–15%) and δ-HCH (6–10%). The mainly composition of lindane is γ-HCH (>99%). Among the HCH isomers, α-HCH is more likely to be transported by air for a long distance, while β-HCH is more resistant to hydrolysis and environmental degradation. Moreover, γ-HCH can be converted to α-HCH in environment. Therefore, the profiles of HCH isomer can reflect the sources and the fate of HCHs in the environment. The composition of HCH isomers distribution patterns are shown in Fig. 2. Concentrations and compositions of HCH isomer were found to be in order β-HCH > γ-HCH > α-HCH > δ-HCH in almost all samples except samples S_1 and S_9. The results suggested that the composition of HCH isomers in the present study was not reflecting the composition of technical grade HCHs. The predominant composition of β-HCH indicates its most stable nature among HCH isomers and resistant to microbial degradation (Ramesh *et al.,* 1991; Lee *et al.,* 2001). Also it should be noted that α-HCH can be converted to β-HCH in the environment (Walker *et al.,* 1999).

The ratio of α- to γ-isomer (α/γ ratios) range from 0.21 to 0.61 were well below those in the technical mixture (i.e., 4–7). The low α/γ HCH ratio in the sediment sample implies the use of lindane in this region (Pandit *et al.,* 2006). High concentration of lindane was observed in sampling stations S_1 and S_9. The average composition of HCH isomers measured in the sediment samples are α-HCH: 15.2%, β-HCH: 38.6%, γ-HCH: 35.8%, δ-HCH: 10.2%. It can be concluded that lindane may used recently in all the agricultural study area. Concentrations of HCHs in sediment samples (5.69–13.59 ng/g) is slightly higher than that reported from the Mandovi river estuary by Iwata *et al.* (1994) and from the estuaries along the west coast by Sarkar *et al.* (1997).

DDTs were detected in all sediment samples, but the contribution of individual metabolites showed differences. The concentration of total DDT reached maximum value at S_3 (18.20 ng/g) followed by S_4 (15.55 ng/g), S_5 (14.35 ng/g) and S_6 (14.21 ng/g). The minimum value of DDT was recorded at S_7 (5.24 ng/g), whereas the other four stations followed almost an equal trend of DDT distribution ranging from 7.47 to 13.01 ng/g. Among the metabolites of DDT, *p,p′*-DDD was found to be much more significant than other metabolites *p,p′*-DDE and *p,p*-DDT. The occurrence of DDT isomer is predominant in the following order: *p,p′*-DDD > *p,p′*-DDT > *p,p′*-DDE. This implies that DDT is likely to be dechlorinated to DDD in the anaerobic condition in deep layer soil (Youfeng *et al.,* 2005). In all the samples, the ratios of DDD/DDE were >1.0. It has also been suggested that DDT is biodegraded to DDD under anaerobic condition (Hitch and Day, 1992). However, the rate of biodegradation of DDT to DDE was low due to lack of aerobic environment. Furthermore, the ratio of (DDE+DDD)/ΣDDTs can be used as an indicative index to assess possible pollution sources (Doong *et al.,* 2002b). The ratio of (DDE+DDD)/ΣDDTs > 0.5 in all the sampling sites, which infers that DDTs input at these sites was historical, and significant degradation has occurred. The total endosulphan (endosulphan I + endosulphan II and endosulphan sulphate) were found in the range between 0.35 and 11.08 ng/g. Among all the nine sampling stations, S_3 has the highest value of 11.08 ng/g. Whereas, no trace of endosulphan were found at sampling stations S_7. However, the endosulphan residues in station S_3 was higher than the other stations where the vegetable and grain crops are grown. Endosulphan sulphate is the metabolite of endosulphan I and II. The occurrence of all these endosulphan in the study area proves that the residues are due to early usage as well as there are still some input sources currently.

The endrin levels (endrin + endrin aldehyde + endrin ketone) were found in the range between 0.73 and 4.33 ng/g. The concentration of various other OCPs in the sediment were in the range of aldrin, nd–2.31 ng/g; dialdrin, nd–2.38 ng/g; heptachlor, nd–0.98 ng/g; heptachlor epoxide, 0.68–3.90 ng/g; chlordane, nd–1.32 ng/g and methoxychlor, nd–2.80 ng/g. The quantifiable amount of these OCPs suggests the frequent use of these pesticides in the study region.

Table 1. Concentration of organochlorine pesticides in sediment and water samples

Organochlorine pesticides	Sediment (ng/g dry wt.) (n = 3)									Water (ng/L) (n = 4)								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9
α-HCH	0.97	1.22	2.51	1.48	1.71	1.63	0.88	0.98	0.75	0.52	0.96	1.73	0.94	1.15	1.32	0.33	nd	nd
β-HCH	2.52	3.31	5.07	4.22	3.93	3.81	2.31	2.98	2.01	0.88	1.18	2.32	2.02	1.52	1.48	1.22	0.68	0.32
γ-HCH	3.51	2.98	4.03	3.72	3.12	2.73	1.98	1.82	3.53	1.12	0.98	2.21	1.41	1.13	1.32	0.72	0.52	0.48
δ-HCH	0.98	1.12	1.98	1.03	0.83	0.72	0.52	0.68	0.43	nd	nd	0.73	0.52	0.48	0.32	nd	0.58	nd
ΣHCHs[a]	7.98	8.63	13.59	10.46	9.59	8.89	5.69	6.46	6.72	2.52	3.02	6.99	4.89	4.28	4.44	2.27	1.78	0.80
p,p′-DDE	1.19	0.73	3.56	2.12	1.91	1.78	nd	0.52	nd	0.52	0.32	1.52	1.21	1.24	0.73	nd	nd	nd
p,p′-DDD	6.81	6.33	8.13	7.22	6.43	7.11	3.12	5.12	4.98	2.14	1.52	3.15	2.63	2.45	1.78	0.94	0.52	0.48
p,p′-DDT	5.01	5.32	6.51	6.21	6.01	5.32	2.12	4.31	2.48	0.96	0.98	2.45	1.64	1.21	1.32	0.32	0.78	0.64
ΣDDTs[b]	13.01	12.38	18.20	15.55	14.35	14.21	5.24	9.95	7.46	3.62	2.82	7.12	5.48	4.90	3.83	1.26	1.30	1.12
Aldrin	1.71	1.52	2.31	1.38	nd	1.63	nd	1.44	0.93	1.11	0.74	0.93	0.78	nd	0.52	nd	0.78	0.62
Dieldrin	0.83	nd	2.38	1.67	1.32	nd	1.12	0.91	nd	0.25	nd	1.10	0.72	0.69	nd	0.32	0.24	nd
Endrin	0.71	1.12	3.10	nd	nd	1.40	1.32	nd	0.93	nd	0.71	1.32	nd	nd	0.62	0.52	nd	0.32
Endrin aldehyde	nd	nd	1.23	0.52	0.63	nd	0.48	0.73	nd	nd	nd	0.52	nd	nd	nd	nd	nd	nd
Endrin ketone	0.32	0.78	nd	1.78	1.40	nd	1.38	nd	0.63	nd	0.51	nd	1.21	0.48	nd	0.98	nd	nd
Heptachlor	0.98	0.19	nd	0.32	nd	0.58	nd	0.63	0.58	0.32	nd	nd	nd	nd	0.25	nd	0.25	nd
Heptachlor epoxide	2.1	2.62	3.90	1.69	2.12	1.21	0.68	1.21	0.78	0.73	0.89	1.32	1.12	1.42	0.54	0.67	0.71	nd
Chlordane	0.52	nd	nd	nd	0.48	1.32	0.81	nd	0.79	nd	nd	nd	nd	nd	nd	nd	nd	nd
Methoxychlor	nd	0.62	2.80	nd	1.31	1.22	0.98	1.22	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Endosulphan I	nd	3.61	3.98	nd	nd	4.01	nd	1.78	1.92	nd	1.71	2.12	nd	nd	1.10	nd	0.62	0.61
Endosulphan II	nd	2.68	3.01	nd	nd	4.11	nd	nd	nd	nd	1.32	1.78	nd	nd	1.31	nd	nd	nd
Endosulphan sulphate	0.48	3.12	4.09	0.35	0.21	2.11	nd	0.52	0.78	nd	0.91	1.92	1.10	nd	nd	nd	nd	nd
ΣOCPs	28.64	37.27	58.59	33.71	31.41	40.69	17.70	24.85	21.52	8.55	12.73	25.12	15.30	11.77	12.61	6.02	5.68	3.47

nd = not detected; n = number of samples collected from each site.

[a] ΣHCHs include α-HCH, β-HCH, γ-HCH and δ-HCH.

[b] ΣDDTs include *p,p′*-DDE, *p,p′*-DDD and *p,p′*-DDT.

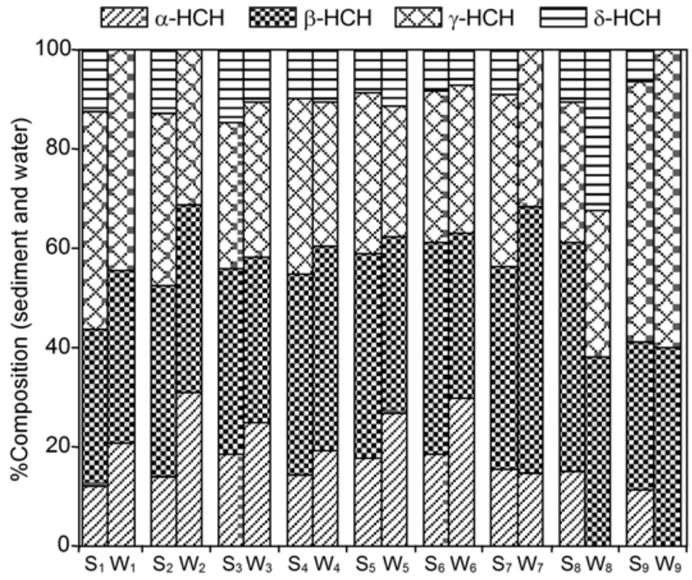

Fig. 2. Composition of HCH isomers in sediments (S) and water (W) from the agricultural sectors of Kanyakumari district

Table 2. Range, mean and standard deviation (SD) of organochlorine pesticides concentrations in sediment and water samples

Organochlorine pesticides	Sediment (ng/g dry wt.)			Water (ng/L)		
	Range	Mean	SD	Range	Mean	SD
α-HCH	0.15–2.51	1.35	3.80	nd–1.73	0.77	2.18
β-HCH	2.01–5.07	3.35	9.50	0.32–2.32	1.29	3.65
γ-HCH	1.82–4.03	3.05	8.62	0.48–2.21	1.10	3.11
δ-HCH	0.43–1.98	0.92	2.61	nd–0.73	0.29	0.83
p,p′-DDE	nd–3.56	1.31	3.71	nd–1.52	0.62	1.74
p,p′-DDD	3.12–8.13	6.14	17.36	0.48–3.15	1.73	4.90
p,p′-DDT	2.12–6.51	4.81	13.60	0.32–2.45	1.14	3.23
Aldrin	nd–2.31	1.21	3.43	nd–0.93	0.61	1.72
Dieldrin	nd–2.38	0.91	2.59	nd–1.10	0.37	1.04
Endrin	nd–3.10	0.95	2.70	nd–1.32	0.39	1.09
Endrin aldehyde	nd–1.23	0.40	1.13	nd–0.52	0.06	0.16
Endrin ketone	nd–1.78	0.70	1.98	nd–1.21	0.35	0.99
Heptachlor	nd–0.98	0.36	1.03	nd–0.32	0.09	0.26
Heptachlor epoxide	0.68–3.90	1.81	5.12	nd–1.42	0.82	2.32
Chlordane	nd–1.32	0.44	1.23	nd	–	–
Methoxychlor	nd–2.80	0.91	2.56	nd	–	–
Endosulphan I	nd–4.01	1.70	4.81	nd–2.12	0.68	1.93
Endosulphan II	nd–4.11	1.09	3.08	nd–1.78	0.49	1.38
Endosulphan sulphate	nd–0.21	1.30	3.66	nd–1.92	0.44	1.24

nd = not detected.

Results are given in Table 2 present the total concentration, mean concentration and standard deviation of OCPs in water samples. The concentration range found in water samples from nine collection sites are HCHs (α-HCH + β-HCH + γ-HCH + δ-HCH) 0.80 to 6.99 ng/L; DDTs (*p,p′*-DDE + *p,p′*-DDD + *p,p′*-DDT) 1.12 to 7.12 ng/L; total endrin (endrin + endrin aldehyde + endrin ketone) nd–1.84 ng/L; total cyclodiene (aldrin + dieldrin + heptachlor + heptachlor epoxide) 0.62 to 3.35 ng/L; total endosulphan (endosulphan I + endosulphan II + endosulphan sulphate) nd–5.82 ng/L.

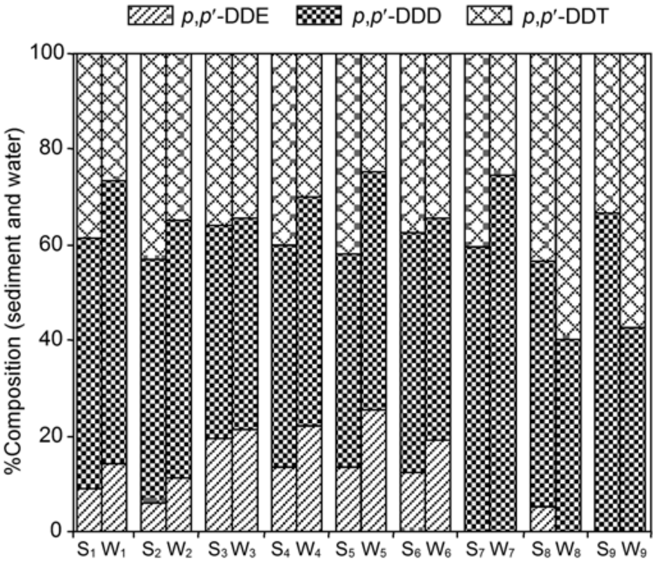

Fig. 3. Composition of DDTs in sediments (S) and water (W) from the agricultural sectors of Kanyakumari district

Among the HCH isomers the dominant isomers are β-HCH (11.62 ng/L) and γ-HCH (9.84 ng/L). The α-HCH/ γ-HCH ratio can be used to identify the source of HCHs in water (Maldonado and Bayona, 2002; Zhang *et al.*, 2003). In this study, the -HCH/γ-HCH ratio in surface water range between 0.45 and 1.01. The results showed that the -HCH/γ-HCH ratio was below 1 in all the sampling stations except W_5, indicating lindane as the HCH source. Higher ratios may be explained by the use of technical HCH mixtures in the part or due to photochemical transformation of γ-HCH into α-HCH in the atmosphere with the subsequent deposition in the surface water.The ratios of DDE/ΣDDTs and DDD/ ΣDDTs can be used to assess how recent DDT contaminations occurred in the environment (Maldonado and Bayona, 2002). In this study the DDE/ ΣDDTs and DDD/ΣDDTs ratios in surface water ranged between nd–0.25 and 0.40–0.74. In all the sampling stations the ratios are below unity suggested the early usage of DDT. The percentage composition of HCHs and DDTs are shown in Fig. 3. Moreover endosulphan I > endosulphan II in water, indicated there are still some input source currently. All the 19 OCPs have been identified in the sediment samples whereas, chlordane and methoxychlor were not identified in any of the water samples. Sampling station 3 (S_3 and W_3) was highly contaminated with OCPs. Severe contamination may be due to the collective runoff from adjacent paddy field and horticultural properties where vegetables, banana and grain crops are grown.

CONCLUSION

This study has provided the first data on the levels of persistent chlorinated pesticides in sediment and surface water of the prime agricultural area of the Kanyakumari district, Tamil Nadu, India. The results indicated that the concentrations of HCHs were lower than those of DDTs. This may be due to their differences in physico-chemical and biosolubility properties. The predominant isomer DDD observed in most of the sampling stations suggested the anaerobic degradation of DDT.

The presence of the β-isomer HCH followed by the γ-isomer was detected in both sediment and surface water samples, in all studied areas, indicating lindane as the main HCH source. The results obtained in this study show that there still a variety of organochlorine pesticides are being used in this region. Pesticides transported to the aquatic environment are primarily of agricultural origin. So further work is needed to determine the bioaccumulation of OCPs in food web and the associated risks to the ecosystem and human health.

REFERENCES

Bhattacharya, B., Sarkar, S. K. and Mukherjee, N. (2003). Organochlorine pesticide residues in sediments of a tropical mangrove estuary, India; implications for monitoring. Environ. Int., **29**, 587–592.

Chau, K. W. (2005). Characterization of transboundary POP contamination in aquatic ecosystems of Pearl River delta. Mar. Pollut. Bull., **51**, 960–965.

Colombo, J. G., Khali, M. F., Horth, A. C. and Catoggio, J. A. (1990). Distribution of chlorinated pesticides and individual polychlorinated biphenyls in biotic and abiotic comportments of the Rio de La Plate. Environ. Sci. Technol., **24**, 498–505.

Doong, R. A., Peng, C. K., Sun, Y. C. and Liao, P. L. (2002a). Composition and distribution of organochlorine pesticide residues in surface sediments from the Wu-Shi River estuary, Taiwan. Mar. Pollut. Bull., **45**, 246–253.

Doong, R. A., Sun, Y. C., Liao, P. L., Peng, C. K. and Wu, S. C. (2002b). Distribution and fate of organochlorine pesticide residues in sediments from the selected rivers in Taiwan. Chemosphere, **48**, 237–246.

Fytianos, K., Meesters, R. J. W., Schroder, H. Fr., Gouliarmou, B. and Gantidis, N. (2006). Distribution of organochlorine pesticides in surface water and sediments in Lake Volvi (northern Greece). Int. J. Environ. Anal. Chem., **86**, 109–118.

Guzzella, L., Roscioli, C., Vigano, L., Saha, M., Sarkar, S. K. and Bhattacharya, A. (2005). Evolution of the concentration of HCH, DDT, HCB, PCB and PAH in the sediments along the lower stretch of Hugli estuary, West Bengal, northeast India. Environ. Int., **31**, 523–534.

Hitch, R. K. and Day, H. R. (1992). Unusual persistence of DDT in some western USA soil. Bull. Environ. Contam. Toxicol., **48**, 259–264.

Iwata, H., Tanabe, S., Sakai, N., Nishimura, A. and Tatsukawa, R. (1994). Geographical distribution of persistent organochlorines in air water and sediments from Asia and Oceania, and their implications for global redistribution from lower latitudes. Environ. Pollut., **85**, 15–33.

Jeyakumar, T., Birla Minimezh Ezhil, V., Anbu, M. and Anita Ben, L. (2009). Distribution of organochlorine pesticide residues in surface sediments from selected areas in Kanyakumari district, Tamil Nadu, India. Pollut. Res., **28**, 399–404.

Lee, K. T., Tanabe, S. and Koh, C. H. (2001). Distribution of organochlorine pesticides in sediments from Kyeonggi Bay and nearby areas, Korea. Environ. Pollut., **114**, 207–213.

Maldonado, C. and Bayona, J. M. (2002). Organochlorine compounds in the Northwestern Black Sea water, distribution and water column process. Estuar. Coast. Shelf Sci., **54**, 527–540.

Nakata, H., Kawazoe, M., Arizono, K., Abe, S., Kitano, T., Shimada, H., Li, W. and Ding, X. (2002). Organochlorine pesticides and polychlorinated biphenyl residues in foodstuffs and human tissues from China: Status of contamination, historical trend, and human dietary exposure. Arch. Environ. Contam. Toxicol., **43**, 473–478.

Pandit, G. G., Sahu, S. K., Sharma, S. and Puranik, V. D. (2006). Distribution and fate of persistent organochlorine pesticides in coastal marine environment of Mumbai. Environ. Int., **32**, 240–243.

Pham, T., Lum, K. and Lemieux, C. (1996). Seasonal Variation of DDT and its metabolites in the St. Lawrence River (Canada) and four of its tributaries. Sci. Total Environ., **179**, 17–26.

Quan, X., Niu, J. F., Chen, S., Chen, J. W., Zhao, Y. Z. and Yang, F. L. (2003). Effects of Fe_2O_3 organic matter and carbonate on photocatalytic degradation of lindane in the sediment from Liao river, China. Chemosphere, **52**, 1749–1755.

Rajendran, R. B. and Subramanian, A. (1997). Pesticide residues in water from river Kaveri, South India. Chem. Ecol., **13**, 223–236.

Ramesh, A., Tanabe, S., Murase, H., Subramanian, A. N. and Tatsukawa, R. (1991). Distribution and behaviour of persistent organochlorine insecticides in paddy soil and sediments in the tropical environment: A case study in south India. Environ. Pollut., **74**, 293–307.

Sankararamakrishnan, N., Sharma, A. K. and Sanghi, R. (2005). Organochlorine and organophosphorus pesticide residues in ground water and surface water of Kanpur, Uttar Pradesh, India. Environ. Int., **31**, 113–120.

Sarkar, A., Nagarajan, R., Chaphadkar, S., Pal, S. and Singbal, S. Y. S. (1997). Contamination of organochlorine pesticides in sediments from the Arabian sea along the west coast of India. Water Res., **31**, 195–200.

Sarkar, A. and Sen Gupta, R. (1991). Pesticide residues in sediments from the west coast of India. Mar. Pollut. Bull., **22**, 42–45.

Sujatha, C. H., Nair, S. M., Kumar, N. C. and Chacko, J. (1993). Distribution of organochlorine pesticides in a tropical waterway: HCH and its isomers. Toxicol. Environ. Chem., **39**, 103–111.

Sujatha, C. H., Nair, S. M., Kumar, N. C. and Chacko, J. (1994). Distribution of DDT and its metabolites in an Indian waterway. Environ. Toxic. Water, **9**, 155–160.

Tanabe, S., Iwata, H. and Tatsukawa, R. (1994). Global contamination by persistent organochlorine and their ecotoxicological impact on marine mammals. Sci. Total Environ., **154**, 163–177.

Tkalin, A. V. (1996). Chlorinated hydrocarbons in coastal bottom sediments of the Japan sea. Environ. Pollut., **91**, 183–185.

Walker, K., Vallero, D. A. and Lewis, R. G. (1999). Factors influencing the distribution of lindane and other hexachlorocyclohexanes in the environment. Environ. Sci. Technol., **33**, 4373–4378.

Willett, K. L., Ulrich, E. M. and Hites, A. (1998). Differential toxicity and environmental fates of hexachlorocyclohexane isomers. Environ. Sci. Technol., **32**, 2197–2207.

Youfeng, Z., Hui, L., Zhiqun, X., Hangxing, C. and Xiaobai, X. (2005). Organochlorine pesticides (DDTs and HCHs) in soils from the outskirts of Beijing, China. Chemosphere, **60**, 770–778.

Zhang, Z. L., Hong, H. S., Zhou, J. L. and Yu, G. (2003). Fate and assessment of persistent organic pollutants in water and sediments from Minjiang River estuary, Southeast China. Chemosphere, **52**, 1423–1430.

Zhou, R., Zhu, L., Yang, K. and Chen, Y. (2006). Distribution of organochlorine pesticides in the Tonghui River of Beijing, China. Environ. Pollut., **130**, 249–261.