ORGANOCHLORINE INSECTICIDE CONTAMINATION IN THE INLAND ECOSYSTEMS OF KERALA

By

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THESIS

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Dedicated to My Father

Late Robert Joseph

DECLARATION

I hereby declare that this thesis entitled **"ORGANOCHLORINE INSECTICIDE CONTAMINATION IN THE INLAND ECOSYSTEMS OF KERALA"**, is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or society.

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CERTIFICATE

Certified that this thesis entitled **"ORGANOCHLORINE INSECTICIDE CONTAMINATION IN THE INLAND ECOSYSTEMS OF KERALA"** is a record of research work done independently by **Kum. Rosalind. R.S** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Rosalind.R.S

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INTRODUCTION

INTRODUCTION

Kerala blessed with vast inland water system has a number of backwater and fresh water lakes, ponds, rivers and canals distributed all over the state. These water bodies are highly prone to contamination with insecticides, industrial waste discharges, dead animals, house hold and farm wastes etc by virtue of the peculiar cultivation practices followed in some of the areas and the dence human habitations in the adjacent uplands.

The system of 'punja cultivation' of rice prevalent in Kuttanad, situated among the Vembanad lake and adjascent rivers, is unique in the country. Extensive areas of the lake, lying 3-4 meters below sea level, are demarcated with strong bunds and dewatered periodically to raise short or medium duration varieties of rice. One to three such crops are grown annually keeping the area contigously flooded with the lake during the monsoon periods only. The land thus reclaimed being highly fertile, the productivity of the crop is very high and the enthusiastic farmers raise the high yielding varieties alone adopting very intensive cultivation practices. Natural sequence or well nurtured high yielding crop is prone to the heavy incidence of pests and diseases. For protecting such valuable crops heavy use of pesticides had been in vougue in the area during the past several decades and this has caused significant pollution of the cultivated areas. Flooding during the monsoon spreads the insecticide residues over the entire lake ecosystem.

Further in the absence of protected water supply system in the entire area, these open water bodies are the major source of water for majority of the population for their house hold purposes and even for drinking. This poses serious health hazards to the human population and other domestic animals.

Such Punja cultivation is prevalent along the upper portions of the fresh water lakes in the state also. Besides in the uplands adjascent to the boundaries of the lakes, lots of vegetables are grown exploiting the perennial irrigation source in the lakes. Vegetables being a lucrative crop and highly suceptible to pests and diseases are often grown under intensive pesticide cover. Surface run off, accidental spills and drift from the adjascent areas pollute the water bodies significantly. From the lakes water is being distributed to the human population residing even in remote areas through the recently developed rural drinking water supply schemes. The insecticide content of this drinking water, which seldom gets screened for the contaminant, may cause serious chronic effects on the users in the long run.

Though the problem of insecticide contamination of the lake ecosystem in the state assumes importance and it has not been systematically studied so far. A few random samples collected from Kuttanadu area were analysed by a team of Indo Norwegian scientists in 1989 and recently by Sunil Kumar *et al* (1994). These studies indicated the existence of insecticide residue problem in Kuttanadu ecosystem. The insecticide contamination of fresh water ecosystems of the state has not been investigated so far.

In this context preliminary investigations were undertaken to assess the extent of insecticide pollution of the back water and fresh water ecosystems of Kerala. The organochlorine insecticides which are highly persistent, when compared to the organophosphates, carbamates and pyrethroids used in the area, alone were included in the studies. The survey was conducted with the following objectives.

1. To assess the level of organochlorine insecticide contamination of water in the ecosystems.

2. To assess the accumulation of insecticide residues in the sediments of ecosystem.

3. To assess the extent of pollution of organochlorine insecticide residues in the fish.

4. To make a comparative assessment of the insecticide pollution in back water and fresh water ecosystems of the state.

REVIEW OF LITERATURE

01. REVIEW OF LITERATURE

Investigations were undertaken on the organochlorine contamination in the different components of the inland ecosystem viz. water,sediment,fishes and prawns. A brief summary of the relevent findings available in literature regarding organochlorine contamination on the different components of the ecosystem is presented below.

01-01. WATER

Fay and Newland (1972) reported the presence of organochlorine insecticide residues in water from Aransas Bay, Texas. The occurrence was not correlated with the salinity or pH of the water or the percentage organic content of the sediments.

Herzel (1972) made extensive studies on the organochlorine insecticide residues in surface waters in Germany and reported that residues of gamma-BHC (lindane), alpha BHC, alpha-endosulfan and beta-endosulfan were observed frequently in the Main, Regnitz and Rhine rivers. DDT and its metabolites DDD and DDE were found frequently from the Berlin Teltow Kanal where as heptachlor, heptachlor epoxide and dieldrin were detected only rarely.

Hirano and Katada (1975) detected residues of organochlorine pesticides in water of KOSO river and its outflow into the sea at Tosa Bay, Japan. Five years after the prohibition of the use of organochlorines, four isomers of BHC were noticed widely in the river water and sea

surface water, the amounts being upto 70 ng/l for alpha-BHC, 30 ng/l for beta-BHC, 40 ng/l for gamma-BHC and 10 ng/l for delta-BHC. Levels of BHC in the water appeared to increase from spring to summer and then to decline in autumn.

Dieldrin the epoxide of aldrin was detected in water from Des Moines River, Iowa by Kellogg and Bulkley (1976).

Concentration of lindane, alpha-HCH, aldrin and beta-endosulfan were observed in surface waters in western Canada (Gummer, 1979). At times, the concentration of alpha-HCH and lindane exceeded 0.01 mg/l.

Pillai and Agarwal (1979) reported residues of DDT ranging from 0.062 to 0.963 ppb in water samples collected from Yamuna, Delhi.

Water samples collected from Ludhiana and Muktsar (Punjab) were contaminated with residues of HCH upto 0.9 ppb (Kalra and Chawla, 1981).

The studies conducted by Raju *et al* (1982) revealed that all the water samples collected from rural areas of Mysore district invariably contained residues of alpha (127-830 ppb), beta (60-830 ppb), gamma (150 - 1200 ppb) and total HCH (127-2360 ppb).

Thakkar and Pande (1984) noticed the presence of organochlorine pesticides in the water resources of rivers Yamuna, Ganges and Hooghly from Delhi, Kanpur and Calcutta respectively. Parts per trillion levels of lindane, aldrin, dieldrin, heptachlor, heptachlor epoxide and DDT have been observed in most of the samples. Results indicated definite contamination of water resources with organochlorine pesticides.

Onodera and Tabucanon (1986) detected organochlorine pesticide residues including HCH, heptachlor, aldrin, dieldrin and DDT in the lower Chao Phraya River and Klongs along the river in the metropolitan area of Bangkok and Thailand. The residues of the pesticides averaged 0.233 and 0.1 mg/l in April and October respectively. The concentrations of alpha-BHC, aldrin and dieldrin in the river water were 3-10 times higher in the dry season than in the rainy season and the residues were concentrated in the river water from the river mouth to 30 Km upstream.

Shrivastava *et al* (1987) reported residues of HCH in water samples (0.0025 to 0.340 ppm) collected from Malwa region (Madhya Pradesh)

The groundwater of Colombian eastern plains were contaminated by insecticides aldrin and dieldrin upto 0.3 ppm and DDT and lindane upto 1.9 ppm (Avellaneda, 1988).

Traces of organochlorine insecticide residues were found in the river water from natural resources of the Aconcagua Valley (Ciudad and Moyano, 1988).

Johnson *et al* (1988) reported the presence of DDT compounds including p.p'-DDT and p.p'-DDE in water of the Yakima River Drainage, Washington.

Kaphalia *et al* (1988) observed residues of HCH (2.5 to 73.5 ng/l) and DDT (2.9 to 21.8 ng/l) in water samples collected from Srinagar (J&K).

Varying concentrations of organochlorine insecticides and their metabolites lindane. heptachlor, aldrin, p.p'-DDE, p.p'-DDD and p.p'-DDT were determined in water samples taken

from two lakes in Rajasthan in June 1985 to July 1986 (Kumar *et al*, 1988). In Mahalon lake the residues were highest (6.6 mg/l) during october while in Jalmahal lake, they were highest (9.6 mg/l) in September. In both lakes residues of DDT exceeded the recommended limit for water quality criteria. Lindane was found in most of the samples in low quantities followed by aldrin.

Paasivirta *et al* (1988) detected low levels of organochlorine insecticide residues (0.1 - 2.1 ng/g) with the exception of dieldrin (4 - 36 ng/g) and its phenometabolite tanzadrin (10 - 250 ng/l) from the Nyumba Ya Mungu Reservoir in Tanzania.

Water from Nile - Egypt contained residues of alpha BHC, lindane, aldrin, dieldrin, endrin and p.p'-DDT during February to June 1986 (Razik *et al.* 1988).

Residues of alpha and gamma isomers of HCH (0-400 ng/l), DDT (4000 ng/l) and endosulfan (66-1114 ng/l) were detected in the water samples of Kuttanadu (Anon., 1989).

Water samples collected from rivers Khan (near Indore, Madhya Pradesh), Kshipra (near Ujjain, Madhya Pradesh) and Chambal (near Kota, Rajastan) were contaminated with varying levels of HCH, DDT and aldrin (Kulshrestha *et al*, 1989).

The organochlorine insecticides were uniformly distributed in water samples collected from Donana National Park, Spain in 1982 - 86 with the exception of DDT in higher amounts than the recommended maxima for waters (Rico *et al*, 1989).

Sarkar and Gupta (1989) determined residues of several organochlorine insecticides in the water of central west coast of India using an in situ sampler, the residue levels being 0.26 - 9.4

ng/l for lindane, 1.4 -9.8 ng/l for aldrin and 2.1 to 50.9 ng/l for dieldrin. pp'-DDT was the most abundant metabolite of DDT. Among the DDT metabolite pp'-DDE ,o.p'-DDE and o.p'-DDD were detected whereas p.p'-DDD was not detected at all.

DDT (0.101 to 0.224 ppb), endosulfan (0.093 to 0.657 ppb), heptachlor (0.006 to 0.696 ppb) and lindane (0.006 to 8.255 ppb) were detected in water samples collected from Madras coast indicating pollution load (Sivaswamy, 1989).

Organochlorine insecticide residues including pp'-DDE, pp'-DDD (pp'-TDE), pp'-DDT, alpha-HCH, beta-HCH, gamma-HCH, aldrin and heptachlor in water were detected in all the samples collected from four different sites of the Mahala water reservoir in India (Bakre et al, 1990). Monthly total organochlorine residue levels in water ranged between 1.07 and 81.23 mg/l. Isomers of HCH predominated followed by aldrin, total DDT and heptachlor residues.

Dikshith *et al* (1990) reported that the drinking water sources in Bhopal was contaminated with residues of HCH (1.576 to 15.58 ppm) and DDT (3.153 to 771 ppm)

Halder *et al* (1990) reported residues of BHC isomers including alpha, beta, gamma and delta occurring in Ganga waters; the concentration ranged from 0.001 - 0.002 ppm in 21 out of 36 samples analysed.

Residues of alpha-HCH, beta-HCH, pp;-DDT, pp'-DDD and pp'-DDE were detected in Vellar river waters in Tamilnadu from December 1987 to January 1989. (Ramesh *et al*, 1990)

Sunilkumar *et al* (1994) reported detectable levels of alpha (0.036 - 0.241 ppt) and gamma (trace to 0.138 ppt) isomers of HCH in water collected from Kuttanadu.

01-02. SEDIMENT

Fay and Newland (1972) reported the presence of organochlorine insecticides in sediments collected from Aransas, Bay, Texas.

Residues of chlordane, DDE, and DDT were detected in the bottom material from 26 streams that ultimately drain into San Franscisco Bay, California (Law and Georlitz, 1974). These compounds were present virtually in all the samples analyzed. Chlordane was present in 92% of the samples at concentrations ranging from one to more than thousand microgram per kilogram. Concentrations of DDT and its metabolites was greater than that of chlordane in some of the samples.

Bottom muds of Koso River, Kochi which drains into Bay, Japan were contaminated with residues of alpha-HCH and gamma-HCH, the levels being about 50 times as high as in water (Hirano and Katada, 1975).

Joshi (1985) found DDT residues ranging from 17-89 ppb and HCH from 21-70 ppb in sediment samples from Bhagirathi stretch of Ganga River.

Martin and Hartman (1985) reported the presence of organochlorine pesticides in sediment samples collected in 1980-82 from riverine and pothole wetlands at 17 locations in the North Central United States. Concentrations were above minimum detection limits (5 ng/g of organochlorines) in less than 4% of the samples analyzed.

Onodera and Tabucanon (1986) detected the presence of organochlorine pesticides including HCH, heptachlor, aldrin, dieldrin, and DDT in sediment from Chao Phraya River and

Klongs, Thailand. Residues in river sediments were concentrated 30-60 km up the river which is 200-350 times higher than those found in river water.

Distribution of HCH and DDT concentration in the upper sediment layer of the Xiamen harbour was reported by Shumei *et al* (1986). Concentrations ranged from 1.5 to 27 microgram/ kg for HCH and 4.5 to 150 microgram/kg for DDT.

Organochlorine insecticides including DDT, HCH, dieldrin, aldrin, endrin, chlordane, heptachlor, endosulfan and methoxychlor were detected in surficial sediments of Manuakau Harbour, Newzealand (Fox *et al*, 1988).

Johnson *et al* (1988) reported the presence of DDT compounds (P.P'-and O.P'-DDT and metabolites DDE and DDD) in bed sediments from the Yakima River drainage in Washington State.

Sediments from the Nyumba ya Mungu Reservoir in Tanzania was contaminated with chlorinated insecticide residues including dieldrin and tanzadrin in higher concentrations (Paasivirta *et al*, 1988).

DDT, dieldrin, lindane and chlordane were identified as the contaminants of the Manukau Harbour Newzealand (Hume, [illegible] *et al*, 1989).

Residues of alpha and gamma isomers of HCH (0-20000 ng/l), and DDT (up to *100,000* ng/l) were detected in the samples of sediment collected from Kuttanadu in Kerala (Anon., 1989a).

Sediment samples collected from ten stations along the Madras coast, from Ennore to Thiruvanmiyur, were analyzed for organochlorine pesticides (Sivaswamy, 1989). DDT (0.0004 to 2.748 ppm), endosulfan (0.004 to 3214.68 ppm), heptachlor (0.0004 to 8.819 ppm) and lindane (0.0003 to 10.731 ppm) were quantified in high concentrations in these samples indicating pollution load along the Madras coast.

Gilliom and Clifton (1990) detected residues of organochlorine pesticides including DDD, DDE, DDT and dieldrin in bed sediments of the San Joaquin River and its tributaries in California. They were widespread in the fine grained bed sediments, despite little or no use of these insecticides for more than 15 years.

Sediment collected from an agricultural water shed in South Carolina was contaminated with endosulfan (Chandler and Scott, 1991).

Ford and Hill (1991) reported residues of organochlorine pesticides in soil sediments in the upper steele Bayou Watershed of Mississippi. Residues ranged from 0-4.6 mg/kg of 5 compounds detected in soil samples. Biomagnification of organochlorine pesticide residues was evident from soil to mosquito fish (*Gambusia affinis*), a lower secondary consumer and forage fish, two spotted gar (*Lepisosteus oculotus*), a tirtiary consumer.

Traces of alpha (trace to 0.034 ppt), beta (trace - 0.058 ppt) and gamma (trace to 0.03 ppt) isomers of HCH were detected in the samples of sediments collected from Kuttanadu in Kerala (Sunil kumar *et al*, 1994)

01-03. FISH

Fish samples collected from Great Lake and in major river basins throughout the United States of America contained organochlorine insecticides including DDT and its metabolites (upto 45 ppm), dieldrin (upto 2 ppm), heptachlor, heptachlor epoxide and chlordane (Henderson *et al*, 1969).

Organochlorine insecticides like DDT, DDE, DDD and chlordane were detected in fish samples collected from Swedish water (Westoo and Noren, 1970).

Bjerk (1972) reported residues of DDT in Norwegian sprats (*Clupea sprattus*)upto 0.49 ppm and in Herring (*Clupea harengus*) upto 1.3 ppm on a fat basis.

1-hydroxy chlordene, a metabolite of heptachlor was detected in fish from Iowa (Bouderman and Slach, 1972).

Bradshaw *et al* (1972) detected residues of organochlorine insecticides in fish especially DDE upto 956 parts/10^9 DDE.

Total residues of DDT and its metabolites were estimated in flesh only or flesh with skin of white crockers (*Genyonemus lineatus*) caught outside Los Angeles harbour (Castle and Woods, 1972). Total residues were 10.82 and 18.23 microgram per gram without and with skin respectively.

Residues of organochlorine insecticides including dieldrin, p.p'-DDD and p.p'-DDE were detected in fish samples (Fay and Newland, 1972).

Giam *et al* (1972) reported residues of DDT and DDE in fish collected from the Gulf of Mexico and Caribbean sea.

DDT and its metabolites were detected from eels (*Anguilla australis Schmidtii* and *Anguilla diefenbachii*), groper (*Polyprion oxygeneios*) and some flounder (*Rhombosolea plebeia*) and crustacea in the edible flesh ranging from 0-0.2 ppm (Solly and Harrison, 1972).

Residues of heptachlor epoxide, dieldrin and DDT were detected from Smoky Hill River of Western Kansas in trace amounts (Klaassen and Kadoum, 1973).

Kathpal (1974) reported residues of DDT in fish collected from Hyderabad, India.

Chlorinated hydrocarbon insecticides in coastal young of the year finfish, South carolina and Georgia was studied (Reimold and Shealy, 1974). Dieldrin in 2% and DDT and its metabolites in 33% of the samples were detected.

Fish collected from Fraser River, Georgia strait contained residues of p.p'-DDD, p.p'-DDT, p.p'-DDE and heptchlor epoxide (Albright *et al*, 1975).

Veith (1975) reported that mean concentrations of total DDT (p.p'-DDT, o.p'-DDT, p.p'-DDD, and P.P'-DDE) ranged from less than 1 ppm in suckers to approximately 16 ppm in suckers in large lake trout collected from Lake Michigan.

Insecticide contamination with DDT, gamma-HCH and endrin in the Murray-Darling river system was accounted for the decline of the native fish (Cadwallader, 1978).

Fish samples collected from Ludhiana was contaminated with DDT (0.029-2.2 ppm) and HCH (0.023-1.120 ppm) (Anonymous, 1980).

Lakshminarayana (1980) reported the presence of DDT in trace amounts in the samples of fish collected for analysis from Hyderabad.

Bhinge and Banerji (1981) reported residues of DDT, dieldrin, HCH, lindane, aldrin, and heptachlor in fish pomfret (*Pampus argenteus*) and the DDT concentration in various organs of fish ranged from 0.43 to 34.05 ppm.

Fishes including singhara, malhi, rahu, sohal, khangra, sarmahi and chakar collected from Punjab were contaminated with residues of HCH, which ranged from 0.031-0.247 ppm (Kalra and Chawla, 1981).

Trace amounts of DDE was found in fish, *Tilapia* collected from Lake Naivasha (Lincer *et al*, 1981).

An experiment conducted by Joshi (1985) to monitor the pesticide residues in the Bhagirathi Hoogly stretch of the Ganga river system revealed the presence of DDT (31-480 ppb) and gamma-HCH (46-210 ppb) in fish.

Organochlorine pesticides were detected in fish from wetlands in the North Central United States (Martin and Hartman, 1985). The most common compound found in fish was DDE, which was found in 51% of the samples at levels upto 512 ng/g, alpha-HCH was present in 36% of the fish samples, the concentration ranged from *5-27* ng/g and that of DDD in 14% of the

samples at concentration *5-60* ng/g. DDT and dieldrin were detected in fish at relatively low concentrations in less than 10% of the samples.

Mehrotra (1985 a) reported residues of DDT ranging from 0.059-7.575 ppm in samples of prawns collected from Yamuna (Delhi).

Chaudhury (1986,1988) analyzed the market samples of fish which contained endosulfan ranged from 42.7 x 10^{-6} to 87.5 x 10^{-6} ppm.

An experiment to estimate the extent of pesticide contamination in the aquatic environment using fresh water fish as indicator was conducted by Kaphalia *et al* (1986). The fishes including *Bagarius bagarius, Channa punctatus, Cirrhinus reba, Clarias batrachus, Heteropneustes fossilis, Labeo rohita, Macrognathus aculeatus, Mystus seengala, Rita rita, Silonia silonia, Wallogo attu , Natopterus notopterus* and prawns drawn from river Gomti, Lucknow were contaminated with varying *levels of HCH* and DDT in them.

Shrivastava (1987) reported residues of DDT (2.138 ppm) and HCH (0.007-1.244 ppm) in *Labeo gonius* and DDT (1.781 ppm) and Aldrin (0.003-0.976 ppm) in *Channa striatus*, the collected species of fishes from Malwa region (Madhya Pradesh).

Organochlorine residues in the blubber of short finned pilot whales, *Globicephala macrorhynchus* from Ayukava the Pacific coast of Japan was reported by Tanabe *et al*,(1987).

Organochlorine insecticides including chlordane, heptachlor epoxide, p.p'-DDD (4.4'-DDE) and p.p'-DDE (4-4'-DDD/TDE) were detected in common carp collected from Tuttle Creek Lake, Kansas (Arruda *et al*, 1988).

Fish collected from Ribeirao do Lobo reservoir, Brazil was contaminated with organochlorine pesticides (Celeste and Caceres, 1988). Residues of aldrin, HCH, Chlordane, DDE, DDT, dieldrin, endosulfan, heptachlor and lindane were detected.

Fish samples collected from Upper Egypt was contaminated with residues of HCH, lindane, DDT complex, aldrin, dieldrin, heptachlor, heptachlor epoxide and oxychlordane (Dogheim *et al*, 1988).

Johnson *et al* (1988) reported residues of DDT compounds (p.p'-DDT, o.p'-DDT, DDE and DDD) in fish collected from Yakima River Drainage, Washington.

Samples of fish collected from West Bengal revealed the presence of endosulfan ranging from ND-0.367 ppm (Anonymous, 1989).

A study on monitoring and surveillance of residues of organochlorine pesticides in fishes collected from rivers Khan, Kshipra and Chambal was conducted by Kulshrestha *et al* (1989). Residues of HCH, DDT, aldrin and endosulfan were invariably detected in fishes including *Wallago attu, Labeo gonius, Heteropneustes fossilis, Mastacembelus armatus, Channa striatus, Channa marulius, Catla catla, Punctius ticto, Labeo rohita, Channa punctatus, Gudusia chapra, Notopterus notopterus* and *chanda nama* collected from rivers Khan (Indore), Kshipra (Ujjain) and Chambal (Nagda-Kota).

Radhakrishnan and Antony (1989) studied the pesticide residues in marine fishes including black pomfret (*Parastromateus niger*), mackerel (*Rastrelliger Kanagurta*), marine vala (*Chirocentrus sp*) and tuna (*Euthynnus affinis*). Alpha-BHC (0.002 to 0.2 ppm), lindane

(0.0003 to 0.003 ppm), heptachlor (0.0001 to 0.004 ppm), aldrin (0.002 to 0.012), heptachlor epoxide (0.001 to 0.025 ppm), p.p'-DDE (0.001 to 0.003 ppm), p.p'-DDD (0.002 to 0.009 ppm), dieldrin (0 to 0.001 ppm), o.p'-DDT (0.002 to 0.007), endrin (0.003 to 0.08 ppm) and p.p'-DDT (0 to 0.042 ppm) were detected in the fishes. The total concentration of above pesticides were 0.0277, 0.0566, 0.3533 and 0.1026 ppm for mackerel, marine vala, black pomfret and tuna respectively. The highest concentration was found in black pomfret followed by tuna, vala and mackerel and the levels were below the FDA limits to cause any health hazard.

Shailaja and Gupta (1989) reported DDT residues in 4 species of fish collected from Arabian sea.

Chlorinated hydrocarbons including DDT isomers, lindane and dieldrin were detected in fish burbot (*Lota lota*) from remote lakes and rivers in Canada (Muir *et al*, 1990). The predominant compound detected was camphechlor ranging from 1400-1723 ng/g (lipid weight).

Ramotsa *et al* (1990) reported residues of lindane, DDT, DDE and DDD in the commonest fishes pike-perch, carp and bream in Lake Balaton, Hungary between 1976 and 1988.

DDE and dieldrin residues were detected in Lake Ontario lake trout (*Salvelinus-namaycush*) between 1977-1988 (Borgmann and Whittle, 1991).

European eel, *Anguilla anguilla* showed different accumulation pattern for various organochlorine insecticides in their various organs including gill, muscle, liver and digestive

tract (Ferrando *et al*, 1991). Organochlorine insecticide level found in eel indicate not only the high lipid content in the tissues of the fish, but also are indicative of the feeding habits of this aquatic predator.

DDE was detected as the predominant organochlorine compound in the flesh of red mullet (*Mullus barbatus*) from Greek waters (Gregoriades *et al*, 1991).

Kulshrestha (1991) reported that fish pomfret collected from Arabian sea contained HCH (0.004-0.36 ppm) and in Hoogly the level of gamma HCH was 46-210 ppb. In Malwa region the level of HCH was 0.074-1.24 ppm.

Sharma and Dhakad (1995) detected residues of gamma HCH in various organs of fishes ranging from 0.0043 (ovary of *H. fossilis*) to 1.0083 ppm (gills of *Notopterus notopterus*) collected from indore.

MATERIALS AND METHODS

02. MATERIALS AND METHODS

02-01. COLLECTION OF SAMPLES

The inland ecosystems of Kerala viz. Vellayani, Sasthamkotta, and Kuttanadu were selected to assess the extent of contamination with organochlorine insecticides.

02-01-01. AREAS COVERED

1. Vellayani lake.

2. Sasthamkotta lake.

3. Kuttanadu lake.

02-01-02. LOCATIONS:

Samples were collected from three locations of each lake area and one major fish market from each area also was chosen. In Vellayani lake the locations were Vellayani, Kakkamoola and Panangode; the major fish market selected for the study, was at Kakkamoola.

In Sasthamkotta ecosystem, Sasthamkotta, Bharnikkavu and Karalimukku were the three locations and fish market selected was at Sasthamkotta.

In Kuttanadu ecosystem Monkompu, Pulinkunnu and Kumarakom were the locations and the market selected was at Kumarakom.

02-01-03. COMPONENTS SAMPLED :

Water, sediment, fishes viz. pearl spot *(Eteroplus suratensis)*, cat fish *(Heteropneustes fossilis)* and prawns (*Macrobrachium idella idella* - from Vellayani and Sasthamkotta and *M. rosenbergii* - from Kuttanadu). The fish and the prawn samples were collected from different locations and the market.

Replication of the samples : Three

02-02. PROCEDURE FOR RESIDUE ANALYSIS

Analytical procedure followed for the estimation of the chlorinated hydrocarbon insecticides for the different components of the ecosystem are presented below.

02-02-01. RESIDUES IN WATER

Water samples collected from five different spots of the lake from each location site selected for the study were pooled together in a big vessel. After thorough mixing, one litre sample was taken in the collection bottle of 1.5 l capacity and capped (The collection bottle was of high quality dark glass with tellon stopper which was cleaned properly with detergent and tap water and rinsed with distilled water, acetone (A.R. Grade) and finally with hexane (redistilled). Three such samplings were done for each location. The sealed bottles were transported to the laboratory for analysis.

The quantitative analysis of organochlorine insecticides from water was done by the solvent extraction method as described by Takroo and Ray (1987). The solvent used was n-hexane.

02-02-01-01. Extraction:

The water sample was filtered in Whatman filter paper No. 1. and then homogenized by shaking the container at room temperature for ten seconds.

One litre of the homogenized water sample was transferred to a separatory funnel (2 l) with the help of graduated measuring cylinder.

In the case of dirty water samples, twenty grams of anhydrous sodium sulfate was added to the water sample in the separatory funnel to check the emulsion formation during liquid-liquid extraction.

With the help of graduated measuring cylinder 50 ml of distilled n-hexane was added to the separatory funnel through rinsing the sampling container.

After putting the stopper tightly, the mixture in separatory funnel was shaken vigorously for 2-3 minutes with releasing pressure repeatedly in between by opening the stop-cock; so that liquid doesn't come out at all.

The separatory funnel was left on stand for adequate time (about 10 minutes) in order to allow the layers (water and solvent) to separate distinctly. The emulsion formation if observed, the water-solvent inter phase was broken by adding few grains of anhydrous sodium sulfate.

After the layers were separated, the stopper was opened and the aqueous layer transferred to another separatory funnel through stop-cock and upper solvent layer was collected in a 250 ml conical flask. The used separatory funnel was rinsed with 2-3 ml of hexane for 2-3 times and the washings were collected in the same conical flask.

Again 50 ml of fresh hexane was added to the separatory funnel containing the same water sample and partition the hexane layer to the same conical flask containing the previous extract. The separatory funnel was rinsed 2-3 times with 2-3 ml of hexane and washings were collected in the conical flask containing the extract.

The same water was extracted for the third time also with 50 ml hexane in the same way and the solvent, were pooled in the same conical flask.

Drying / De moisturing

Anhydrous sodium sulfate filter column was prepared by putting about 10 g of anhydrous sodium sulfate in a glass column with glass wool pad at bottom to retain sodium sulfate.

The organic solvent was passed through the column thus prepared above and collected in a clean beaker. The column was washed again 2-3 times with 3-4 ml of hexane each time and the washings collected in the same beaker.

Concentration

Propylene glycol (0.5 ml) was added to the hexane extract as a keeper solvent. Then the hexane extract was evaporated at 40°C on a water bath and reduced the volume of extract to ca 5-10 ml.

02-02-01-02. Clean Up

Since more than 90% recovery of organochlorine insecticides were obtained without any clean up, no such procedure was followed for the sample analysis.

02-02-01-03. Estimation

Identification and estimation of residues were done using gas chromatography. (GC).

02-02-02. RESIDUES IN SEDIMENT

Sediment samples were collected from all the three locations of each ecosystem. The samples collected from five spots in the lake area were pooled together and put inside the glass containers. The containers before use were washed with soap and tapwater, distiled water, acetone and finally hexane, the working solvent. The samples were transferred to the laboratory for analysis.

The water layer over the sediment was discarded. The sediment was mixed thoroughly to obtain as a homogeneous sample as possible and transferred to petridishes of 9 cm diameter and was partially air dried for about 3 days at ambient temperatures. The moisture content at this point would be 50-80%.

The quantitative analysis of organochlorine pesticides in the sediment was done by using the methodology described by Sherma and Beroz (1979).

02-02-02-01. Extraction

Twenty five gram of the partially dried sample was taken in a 250 ml beaker. It was mixed well with 25 g anhydrous sodium sulfate using a large spatula and then allowed to stand with occasional stirring for approximately 1 hour.

The sample was then blended in a mixie for about 20 seconds in order to get a free flowable mixture.

Carefully transferred the sample to a stoppered chromatographic column. (2.4 cm diameter) the bottom plugged with glasswool. Then the column was tapped firmly to settle the sediment samples over the glasswool. The mixer chamber was rinsed with small portions of hexane and the rinsings were passed through the column. The column was then eluted with 125 ml of 1:1 acetone : distilled hexane mixture into a 250 ml beaker, the flow-rate being adjusted to 3-5 ml/minute.

The extract was then concentrated to ca 50 ml at a temperature not higher than 55°C. The concentrated eluant was transferred to a 250 ml separatory funnel containing 150 ml of distilled water and 12.5 ml of saturated sodium sulfate solution. The whole contents were shaken for about two minutes.

The water layer was drained into a clean beaker and the hexane layer into another 125 ml separatory funnel.

The water was transferred back into the original separatory funnel and re-extracted with 10 ml of 15% methylene chloride in hexane by shaking the separatory funnel for about two minutes.

The layers were allowed to separate. The water layer was discarded and the solvent extracts were poured into the other separatory funnel containing the first eluant mixture.

The combined solvent extracts were washed by shaking with 50 ml distilled water for 30 seconds. The lower water layer was discarded and the hexane layer was rewashed with 50 ml of distilled water.

After partitioning, the hexane layer was passed through a funnel containing anhydrous sodium sulfate, rinsing the container with 3 portions of ca 5 ml each of hexane.

The extract was concentrated to ca 1 ml in 80°C in a water bath.

02-02-02-02. Silica Gel Fractionation and Clean Up

Activation of silica gel:

Silica gel was activated for 48 hours at 175°C before use. Deactivated silica gel was prepared by adding 1 ml of water to 5 g of silica gel in a vial with teflon lined screw cap giving a thorough shaking. Discard deactivated silica gel after 5 days. Amount of silica gel activated at 175°C be restricted to the quantity needed for immediate deactivation.

Preparation of the column:

A glass column of 30 cm length and 2.4 cm diameter was used for the clean up. Lightly plug the column with a small wad of pre extracted glass wool. Then three gram of anhydrous sodium sulfate was put over this glass wool. Over this layer, three gram of deactivated silica gel was loaded, tapping gently to settle and then top with 2.4 cm of anhydrous sodium sulfate.

The column was pre washed using hexane. When the level of hexane just reached the top surface of the sodium sulfate, quickly place a 15 ml tube under the column and the concentrated 1 ml sample extract was transferred to the column. This tube was washed three times with 1 ml each of hexane and transferred the rinsings to the column. Finally, 6 ml hexane was added to the column. The resultant 10 ml eluant was Fraction.I. There must be no interruption of phase during this step.

Another tube was kept under the column and 15 ml of benzene : hexane (60:40 V/V) eluting solution was passed through the column. This was collected as Fraction II elutate.

Since the organochlorine pesticides were present in FractionsI and II, elution was carried out only for those fractions.

02-02-02-03. Estimation

Estimation of the residues was done using GC.

02-02-03 RESIDUES IN FISH AND PRAWNS

02-02-03-01 Collection of samples

Samples of fish and prawns were collected from the locations and market. The samples from each location were pooled separately and from the composite samples, subsamples weighing 200 gm were drawn for each type. The samples were collected in aluminium foil and brought to the laboratory for cleaning and further analysis.

The residue estimations were done following the procedures given in Anonymous (1979, 1986)

02-02-03-02 Processing of samples for analysis

Samples of the fish *E. suratensis* were prepared by discarding the head, scales, tail, fins, guts and non-edible bones; the skin was not removed. All flesh and skin from head to tail and from top of back to belly on both sides were obtained by filleting.

In the case of *H. fossilis* the skin was removed because it was not used for consumption.

In prawns, head, tail and shells were removed and discarded. Only the edible meat was used for analysis.

The prepared samples were cleaned thoroughly with tapwater and distilled water. Then the samples were homogenized properly and three samples of 20 gm each were taken for analysis.

02-02-03-03. Extraction

The homogenized sample (20g) was blended with 100 ml of acetonitrile: water mixture (65:35) for two minutes. The extract was filtered through buchner funnel and transferred to a 500 ml separatory funnel. 100 ml of hexane was added to the separatory funnel and the contents were shaken vigorously for 1-2 minutes. Then 5 ml of saturated sodium chloride solution and 150 ml of distilled water were added and the whole contents were shaken vigorously for 30-45 seconds by holding the separatory funnel in a horizontal position; then the funnel was left for the separation of the solvents. After partitioning, the aqueous layer was discarded and the

solvent (hexane) was washed [illegible] with 50 ml portions of distilled water. The hexane was then transferred to a clean beaker through a funnel containing anhydrous sodium sulfate after dehydration. The eluted hexane was concentrated to ca 40 ml for acid digestion.

02-02-03-04 Acid digestion / Clean up

Forty milli litre of concentrated sulphuric acid was taken in a burette. The concentrated hexane extract (40 ml) was transferred to a 125 ml separatory funnel and held beneath the burette in wooden stand. The acid was added dropwise to the hexane extract in the separatory funnel. After the digestion was completed the lower acid layer was discarded and the hexane was washed [illegible] with 50 ml each of distilled water discarding the aqueous layer each time. The washing was continued till the hexane layer was made totally acid free. Then the hexane was passed through anhydrous sodium sulfate and the volume reduced to 5-10 ml for final estimation of the residues in GC.

02-02-03-05. Estimation

Estimation of the residues was done using GC.

02-03 RECOVERY TESTS

02-03-01. WATER

The fortification was done at two levels of the alpha, beta, gamma and delta isomers of HCH, DDT and its metabolites and endosulfan and its metabolites; the levels being 1 microgram/ ml and 0.5 microgram/ml of the respective technical materials of the chemicals. Distilled water

was used for fortification. One sample was kept as control and a reagent blank was also run simultaneously. The fortified samples and the control samples were extracted separately three times with 50 ml each of n-hexane. The extracts from each sample were pooled together which were dehydrated by passing through anhydrous sodium sulfate. The volume of the hexane extracts were reduced to ca 10 ml which were used for the final estimation in GC.

02-03-02. SEDIMENT

Sediment sample (25 g dry weight each) were blended with 25 g anhydrous sodium sulfate in a mixie. Then the samples were fortified with 40 ppm solution of alpha, beta, gamma and delta HCH. DDT and its metabolites, endosulfan and its metabolites and kept overnight. Another sediment sample was kept without the addition of insecticide, to serve as the control. A reagent blank was run simultaneously.

A column of 2.5 cm diameter was lightly plugged with prewashed glass wool and layered over with 1.2 cm anhydrous sodium sulfate. This was further layered over by the soil sample (25 gm) prepared as above. The elution was carried out with 125 ml of acetone : hexane (1:1) mixture and the eluate was collected and evaporated to ca 50 ml. The concentrated sample extract was shaken in a separatory funnel with 50 ml of distilled water and 12.5 ml of saturated sodium sulfate solution. The hexane layer was drained into another separatory funnel and the water layer was re-extracted with 10 ml of 15% methylene chloride in hexane. The hexane layers were combined and washed with 50 ml each of distilled water two times. The hexane layer was collected and concentrated to ca 1 ml volume.

To standardize the methodology for getting maximum recovery two cleanup procedures were adopted using alumina / silicagel columns.

02-03-02-01. Alumina Clean up

Alumina was activated at 130°C for 48 hours, and deactivated for use by shaking with 10% distilled water (W/V).

02-03-02-01-01. Preparation of the alumina column

A 22 X 300 mm column was plugged with pre extracted glass wool and anhydrous sodium sulfate was added to a height of 1.2 cm. Stop cock was closed and the column was filled with hexane. The deactivated alumina (30 g) was slowly added to the column allowing all the alumina to settle at the bottom. This was topped with 2.4 cm layer of anhydrous sodium sulfate and the hexane was allowed to drain through the column by opening the stop cock. When hexane was about 0.3 cm above the sodium sulfate layer the stop cock was closed.

02-03-02-01-02 Clean up:

The concentrated extract of ca 1 ml was added to the column followed by three portions of 3 ml each of hexane transferring the rinsings to the column. The stop.cock was opened and the column was eluted with 85 ml of hexane. The eluant was collected and evaporated to ca 5 ml. Estimation was done in GC.

02-03-02-02 Silica gel clean up

Silica gel was activated for 48 hours at 175°C. It was deactivated by adding 1 ml of water to ca 5 gm silica gel in a vial mixing the contents thoroughly, just before use.

02-03-02-02-01 Preparation of the silica gel column

A 22 X 300 mm glass column was plugged with pre washed glass wool. Sodium sulfate was added to a height of 1.2 cm over the glass wool. Three gram deactivated silica gel was added tapping firmly to settle and then topped with 2.4 cm of anhydrous sodium sulfate. Pre washing was done with 10 ml of hexane.

02-03-02-02-02 Clean up

When the last of the prewash hexane just reaches the top surface of the sodium sulfate, a 15 ml centrifuge tube was placed under the column. Then 1 ml of the concentrated extract was loaded to the column followed by three 1 ml washings and finally 6 ml of hexane was added to the column. The resulting 10 ml effluent was Fraction.I and proceeded further as described under 02-02-02-02 to collect fraction II.

Since the organochlorines were extracted into the first and second fractions, elution was carried out only upto Fraction II.

02-03-03 FISH AND PRAWNS

The recovery studies were made following three different extraction methods, the procedures of which are given below.

02-03-03-01 Extraction methods

02-03-03-01-01 Method 1

The homogenised edible portions of fish and prawns were blended in a mixie and 20 gram samples were fortified separately with 50 ppm of alpha, beta, gamma and delta isomers of HCH,

DDT and its metabolites and endosulfan and its metabolites. A control sample and a reagent blank were also run simultaneously. The samples were taken separately in 100 ml stoppered cylinders. 40 ml each of n-hexane and acetone were added and shaken vigorously for 2 minutes. It was allowed to stand for about 20 minutes for the separation of phases. The separated upper hexane layer was drawn with the help of a pipette which was dehydrated by passing through anhydrous sodium sulfate taken in a funnel. The lower phase was re extracted twice with 40 ml portions of n-hexane and collected as before. The combined n-hexane phases were evaporated on a rotary vacuum evaporator to ca 40 ml.

02-03-03-01-02 **Method 2**

Samples were fortified as described under 02-03-03-01-01 . They were blended with 80 ml of 1:1 acetone: hexane mixture for two minutes in a mixie. The extract was filtered through a buchner funnel and transferred to a 125 ml separatory funnel and allowed to stand for few minutes. The upper hexane layer was collected and the lower layer was re extracted two times with 40 ml each of n-hexane. The hexane extracts were pooled together which was dehydrated by passing through anhydrous sodium sulfate. The volume of the extract was concentrated to ca 40 ml.

02-03-03-01-03 **Method 3**

The samples were prepared as in method 1 and were extracted with acetonitrile: water mixture (65:35). The samples were blended with 100 ml of the above mixture in a mixie for two minutes. The extract was filtered through a buchner funnel and transferred to a 500 ml separatory funnel; 100 ml of hexane was added to the separatory funnel and the contents were

vigorously shaken for 1-2 minutes. 5 ml of saturated sodium chloride solution (5 ml) and distilled water (150 ml) were also added. Holding the separatory funnel in horizontal position, the contents were mixed vigorously for 30-45 seconds. Then the funnel was left (15 minutes) for the separation of the solvents. After partitioning, the aqueous layer was discarded and solvent (hexane) was washed two times with 50 ml portions of distilled water. The hexane was then transferred to a clean beaker through a funnel containing anhydrous sodium sulfate for dehydration. The eluted hexane was concentrated to ca 40 ml for acid digestion.

02-03-03-02 Acid digestion / Clean up

Fourty ml of concentrated sulphuric acid was taken in a burette. The concentrated hexane extract (40 ml) was transferred to a 125 ml separatory funnel and held beneath the burette in a wooden stand. The acid was added dropwise to the hexane extract. After the digestion was completed the lower acid layer was discarded and the hexane was washed three times with 50 ml portions of distilled water, discarding the aqueous layer each time. The washing was continued till the hexane layer was made totally acid free. Then the hexane was passed through anhydrous sodium sulfate and the volume was reduced to 5-10 ml.

02-03-03-03 Estimation

Estimation of the residues of organochlorine insecticides was done by using GC. the details of which are given below.

GLC - Model : Chemito 3865

Column : 1.5% ov 17 + 1.95% ov 210

Operating parameters were :

Temperature :

Detector - 220°C Column - 195°C Injection port - 210°C

Carrier Gas Flow : Nitrogen 70 ml/minute

Retention time

Alpha HCH - 1.1 minutes	Beta HCH - 1.7 minutes	Gamma HCH - 1.4 minutes
Delta HCH - 2.0 minutes	o.p'-DDT - 6.32 minutes	p.p'-DDT - 8.36 minutes
p.p'-DDE - 4.46 minutes	p.p'-DDD - 6.96 minutes	Endosulfan I - 3.9 minutes
Endosulfan II - 7.18 minutes	Endosulfan Sulfate - 9.1 minutes	

02-04 STATISTICAL ANALYSIS

Various statistical techniques like analysis of variance and correlation studies were employed on the data to draw a sharper inference. Three factor CRD analysis was conducted to obtain a summary result of the data over the main sources of variation namely sampling components viz. fish, water and sediment areas and isomers. The results are presented based on these analysis.

RESULTS

03 - RESULTS

The fresh water lakes at Vellayani and Sasthamkotta and backwater lake at Kuttanadu were monitored for the residues of organochlorine insecticides. Different components of the lake ecosystem viz water, sediments, and fishes were covered in the survey. Isomers of HCH alone were present in the samples analysed. The results are presented in this chapter.

03-01. RECOVERY OF HCH, DDT AND ENDOSULFAN

The residues of organochlorine insecticides and their isomers/metabolites in the different components of the lake ecosystems were estimated. The recovery of different insecticides are presented in Table. I

03-01-01 WATER

In the case of water, the analysis was done as suggested in the methodology of Takroo and Ray (1987). Since there was more than 90.0 percent recovery in the method followed for all the different insecticides (range 90.2 to 96.1% Table 1) from fortified samples of water, the method was considered adequate and it was adopted for the analysis.

Table. I
Percentage recovery of insecticides in different components by using modification in the methodologies for analysis

	Water*	Sediment		Fish- Methods of extraction			Prawns - Methods of extraction		
Insecticide		Silicagel cleanup	Alumina cleanup	1	2	3	1	2	3
Alpha HCH	92.1	80.0	28.1	23.5	75.8	87.5	24.5	83.2	89.0
Beta HCH	95.3	81.2	27.8	24.1	76.1	90.3	24.3	84.3	92.1
Gamma HCH	96.1	80.1	30.0	26.2	78.3	91.7	23.5	81.2	93.1
Delta HCH	94.1	85.2	29.8	24.3	71.8	90.5	25.0	78.8	92 4
O.P'-DDT	96.1	82.4	27.9	22.6	82.1	92.1	26.2	79.1	94.2
P.P'-DDT	90.4	80.5	31.0	25.1	80.8	85.6	28.1	75.8	88.3
P.P'-DDD	92.9	84.1	29.0	24.8	70.9	86.0	26.3	78.5	88.5
P.P'-DDE	91.5	81.9	28.8	22.0	78.1	85.5	23.5	82.3	87.0
Endosulfan I	90.2	81.2	27.6	21.0	82.5	86.4	23.0	84.5	86 7
Endosulfan II	91.2	80.7	28.1	23.2	83.0	84.8	24.8	78.9	84.0
Endosulfan Sulphate	90.6	83.2	30.8	24.2	81.8	87.0	21.8	80.0	86.4

Methodology of Takroo and Ray (1987)
Details of Method 1, 2, 3 - Refer para 02-03-01-01-01 to -03

03-01-02 SEDIMENTS

The methodology described by Sherma and Beroz(1979), modified using alternate cleanup materials was adopted in the studies (Watts 1979) using alumina/silicagel colums were tried: (Refer para 02-03-02-01-01 to 02-03-02-02-02) the alumina clean up was giving a recovery of 27.6 to 31.0 percent only where as the clean up using silica gel column chromatography was giving a recovery ranging from 80.0 to 85.2% for the different insecticides. Hence the latter was selected and used.

03-01-03 FISH AND PRAWNS

Residues of samples of fish and prawns were estimated adopting the extration methodology suggested by Anonymous (1976) (Method III) was compared with that of Anonymous (1989) (Method I) and the modification made on the latter one (Method II). The results in Table I, showed that among the three solvent mixtures, acetonitrile: water mixture (65:35) gave a better recovery of all the insecticides, the range being 84.8 to 92.1% for fish and 84.0 to 94.2% for prawns.

When the analysis of the different components of the lake ecosystems was done. detectable levels of DDT and its metabolites and endosulfan and its metabolites were not found in any of the components subjected for the studies, though the recovery of the insecticides for the methodology adopted ranged between 80.0 to 96.1% and the sensitivity of the method was upto ppt levels.

03-02. INSECTICIDE RESIDUES IN THE WATER SAMPLES OF FRESH AND BACK WATER LAKES OF KERALA

03-02-02. VELLAYANI LAKE.

Data on the residues of organochlorine compounds detected from different parts of Vellayani lake (Table.2) revealed that all the samples were contaminated with HCH at varying levels.

Table 2.

Residues of HCH in water samples collected from different locations of Vellayani lake.

Location	Residue of HCH (in ppb)				
	Alpha	Beta	Gamma	Delta	Total
Kakkamoola	0.38	BDL	0.31	BDL	0.69
Vellayani	0.21	BDL	0.23	BDL	0.44
Panangode	0.27	BDL	0.20	BDL	0.47

Variations in data not statistically significant.

BDL - Below Detectable Levels.

Among the locations the maximum level of total HCH was found in the samples collected from Kakkamoola, the value being 0.69 ppb. In Panangode and Vellayani the levels of HCH were 0.47 and 0.44 ppb respectively. The residue levels in samples collected from different parts of the lake did not show significant variations.

Considering the various isomers of HCH it was observed that the concentration of alpha HCH was highest in Kakkamoola (0.38 ppb) followed by Panangode (0.27 ppb) and Vellayani (0.21ppb).

Gamma HCH was maximum in samples collected from Kakkamoola followed by Vellayani and Panangode, the residues being 0.31, 0.23 and 0.20 ppb respectively.

Beta and delta isomers of HCH were below detectable levels in the samples collected from this lake.

03-02-02. SASTHAMKOTTA LAKE

The water samples from Sasthamkotta lake (Table 3) subjected to analysis revealed that they were contaminated with different levels of HCH residues.

Table 3

Residues of HCH in water samples collected from different locations of Sasthamkotta lake

Location	Residues of HCH (in ppb)				
	Alpha	Beta	Gamma	Delta	Total
Sasthamkotta	0.10	0.63	0.35	1.27	2.35
Karalimukku	0.33	2.15	0.15	1.63	4.26
Bharnikkavu	0.10	0.28	0.05	0.77	1.30
CD	NS	NS	0.104	NS	NS

N.S: Not Significant

The highest level of total HCH was found in the samples collected from Karalimukku, the level being 4.26 ppb, the major constituent was beta HCH (2.15 ppb). The residues of total HCH seen in the samples collected from Sasthamkotta was 2.35 ppb and Bharnikkavu, 1.30 ppb. Total level of HCH and all the metabolites, except gamma isomer were higher in the water samples collected from Karalimukku and was followed by Sasthamkotta and Bharanikkavu. The residues of total HCH, delta, beta and alpha isomers being 4.26, 1.63, 2.15 and 0.33 ppb respectively at Karalimukku, while the corresponding values for samples from Sasthamkotta were 2.35, 1.27, 0.63 and 0.10 and for samples from Bharanikkavu 1.30, 0.77, 0.28 and 0.10 respectively. The gamma isomer was highest at Sasthamkotta followed by Karalimukku and Bharanikkavu.

03-02-03. KUTTANADU LAKE

The water samples collected from Kuttanadu analyzed for the residues were also contaminated with HCH residues (Table 4). The maximum level of total HCH was found in the samples collected from Monkompu, the level being 6.66 ppb of which the maximum was accounted by beta HCH followed by delta isomer. The amounts of HCH were 6.16 and 4.43 ppb at Kumarakom and Pulinkunnu respectively. In these locations also the highest contributor of total HCH was beta isomer followed by delta isomer.

Table 4.

Residues of HCH in water samples collected from different locations of Kuttanadu

Location	Residues of HCH (ppb)				
	Alpha	Beta	Gamma	Delta	Total
Pulinkunnu	0.16	2.60	0.13	1.54	4.43
Monkompu	0.22	4.13	0.20	2.11	6.66
Kumarakom	0.26	3.50	0.17	2.23	6.16

Variations not statistically significant.

The highest concentrations of beta (4.13 ppb) and gamma (0.20 ppb) HCH were found in the samples collected from Monkompu followed by Kumarakam and Pulinkunnu, the residue levels being 3.50, 0.17 ppb and 2.60 and 0.13 ppb respectively for the two locations.

In the case of alpha and delta HCH residues they were maximum at Kumarakom having 0.26 and 2.23 ppb followed by Monkompu 0.22 and 2.11 ppb and Pulinkunnu 0.16 and 1.54 ppb respectively.

Statistically none of the observations were found to be significantly different.

03-03. INSECTICIDE RESIDUES IN THE SEDIMENT SAMPLES OF FRESH WATER AND BACK WATER LAKE OF KERALA.

03-03-01. VELLAYANI LAKE

Data on the analysis of HCH and its isomers in sediment collected from various locations in Vellayani lake are presented in table 5.

Table 5.

Residues of HCH in sediments collected from different locations of Vellayani lake.

Location	Residues of HCH (ppm)				
	Alpha	Beta	Gamma	Delta	Total
Kakkamoola	0.09	0.83	0.1	1.04	2.06
Vellayani	0.1	1.5	0.06	1.14	2.80
Panangode	0.13	1.09	0.07	1.18	2.47

Variations in data not statistically significant.

Sediment samples collected from different locations of Vellayani lake revealed the presence of all the HCH isomers in varying concentrations.

Residues of total HCH in sediment was found maximum at Vellayani followed by Panangode and Kakkamoola . The residues were 2.80, 2.47 and 2.06 ppm respectively.

The sediment samples of Kakkamoola, Vellayani and Panangode contained 0.09, 0.1 and 0.13 ppm of alpha HCH respectively.

The levels of the residues of beta HCH was maximum at Vellayani followed by Panangode and Kakkamoola, the values being 1.5, 1.09 and 0.83 ppm respectively.

Maximum level of gamma HCH was detected from the samples of sediment collected from Kakkamoola (0.1 ppm) followed by Panangode (0.07 ppm) and Vellayani (0.06 ppm).

The most predominant isomer was delta which was maximum at Panangode (1.18 ppm) and minimum at Kakkamoola (1.04 ppm).

None of the observations made on the residue status in the different locations were found to be significant.

03-03-02. SASTHAMKOTTA LAKE

As in Vellayani lake, data relating to various locations of Sasthamkotta lake revealed the presence of all the isomers of HCH (Table 6).

Table 6.

Residues of HCH in sediments collected from different locations of Sasthamkotta lake.

Location	Residue of HCH (ppm)				
	Alpha	Beta	Gamma	Delta	Total
Sasthamkotta	0.14	0.22	0.03	0.24	0.63
Karalimukku	0.21	0.26	0.04	0.18	0.69
Bharnikkavu	0.07	0.10	0.03	0.15	0.35
CD	0.06	NS	NS	NS	NS

NS: Not statistically significant

Residues of total HCH in sediments were found to be maximum at Karalimukku followed by Sasthamkotta and Bharnikkavu, the residue levels being 0.69, 0.63 and 0.35 ppm respectively. The major constituent of total HCH in sediments collected from Sasthamkotta and Bharanikkavu were delta HCH while that of the same from Karalimukku was beta HCH. No statistical difference was observed between the locations.

The alpha HCH in sediment varied from 0.07 (Bharanikkavu) to 0.21 ppm, the maximum of which was at Karalimukku (0.21 ppm). In Sasthamkotta the residue was 0.14 ppm. Statistically the samples collected from Sasthamkotta and Karalimukku showed significantly higher residues of alpha compared to Bharnikkavu.

The residues of beta and gamma HCH were maximum at Karalimukku followed by Sasthamkotta and Bharnikkavu, the values being 0.26, 0.22, 0.1 ppm for beta and 0.04, 0.03 and 0.03 ppm for gamma respectively.

But in the case of delta HCH it was maximum at Sasthamkotta followed by Karalimukku and Bharanikkavu; the residues were 0.24, 0.18 and 0.15 ppm respectively.

03-03-03 KUTTANADU LAKE

As in the previous two lakes all the four isomers of HCH were detected in sediment samples collected from Kuttanadu region. (Table. 7)

Table 7.

Residues of HCH in sediment samples collected from different locations of Kuttanad.

Location	Residue of HCH (ppm)				
	Alpha	Beta	Gamma	Delta	Total
Pulinkunnu	0.18	0.84	0.04	0.67	1.73
Monkompu	0.27	2.97	0.14	2.05	5.43
Kumarakom	0.05	0.43	0.10	0.39	0.97
CD	0.06	1.09	NS	0.59	1.74

NS: Not statistically significant

Total HCH residues were maximum in sediment samples collected from Monkompu, the level being 5.43 ppm. This was followed by Pulinkunnu(1.73ppm). In all the locations, the maximum contributor of total HCH was beta followed by delta HCH. Statistically, the total residue levels detected in the sediment samples collected from Monkompu differed significantly from the levels at Pulinkunnu and Kumarakom.

Maximum residues of alpha, beta, gamma and delta HCH in sediment were found at Monkompu the levels being 0.27, 2.97, 0.14 and 2.05 ppm respectively. Statistically significant difference was noticed between the different catching sites of Kuttanadu for all the isomers except gamma HCH residues.

Excepting the gamma isomer, the alpha, beta and delta were found to be more in the sediments from Pulinkunnu than in Kumarakam. The residues were 0.18, 0.84 and 0.67 ppm for Pulinkunnu and 0.05, 0.43, 0.39 ppm for Kumarakam respectively. The gamma HCH level was more in Kumarakam (0.1 ppm) compared to Pulinkunnu (0.04ppm).

03-04. INSECTICIDE RESIDUES IN DIFFERENT SPECIES OF FISH COLLECTED FROM FRESH WATER AND BACK WATER LAKES OF KERALA.

03-04-01 VELLAYANI LAKE

In the Vellayani lake area, three locations were selected for studying the residues of insecticides in three different fish species. The locations were Kakkamoola, Vellayani and Panangode and the fish species were *Eteroplus suratensis*, *Heteropneustes fossilis* and

Macrobrachium idella idella. Samples of these species of fishes were collected also from the local market at Kakkamoola and were analysed for the organochlorine residues.

03-04-01-01. Kakkamoola

Table 8.

Residues of HCH in different fish species occuring at Kakkamoola area of the Vellayani lake

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E suratensis	0.012	BDL	0.016	BDL	0.028
H. fossilis	0.01	BDL	0.005	BDL	0.014
M. idella idella	0.008	0.11	0.006	0.123	0.247
CD	NS	NS	NS	NS	0.0485

BDL - Below Detectable Levels

NS: Not significant

Most of the fish samples collected from Kakkamoola contained all the four isomers of HCH. Total HCH was maximum in prawn samples (0.247 ppm) compared to *Heteropneustes fossilis* (0.014 ppm) and *E. suratensis* (0.028 ppm). Alpha and gamma isomers of HCH were maximum in *E. suratensis*, the levels being 0.012 and 0.016 ppm respectively. Statistically the samples of *M. idella idella* contained significantly higher amounts of total HCH compared to other two fish species.

03-04-01-02. Vellayani

Table 9.

Residues of HCH in different fish species occuring at Vellayani locations of the Vellayani lake

Fish Species	Insecticide residues of HCH (ppm)				
	Alpha	Beta	Gamma	Delta	Total
E.suratensis	0.008	BDL	0.006	BDL	0.014
H. fossilis	0.014	BDL	0.008	BDL	0.022
M. idella idella	0.008	0.102	0.006	0.093	0.210
CD	NS	NS	NS	NS	0.048

BDL - Below Detectable Levels

NS: Not significant

Among the samples collected from Vellayani, the highest level of alpha (0.014 ppm) and gamma (0.008 ppm) isomers of HCH were detected in the samples of *H. fossilis* followed by *E suratensis* and *M. idella idella* each with 0.008 and 0.006 ppm of the above isomers respectively. As all the four isomers were detected in the *M. idella idella*, the total HCH was maximum in this species (0.21 ppm) followed by *H.fossilis* (0.022 ppm) and *E.suratensis* (0.014 ppm). Statistically the samples of *M. idella idella* showed significant difference for total HCH compared to other fish species which were on par.

03-04-01-03. Panangode

The alpha HCH residue in the different fishes ranged from 0.01 ppm (*M. idella idella*) to 0.024 ppm (*H. fossilis*); *E suratensis* containing 0.022 ppm. The maximum residues of beta and delta isomers were noticed in the samples of *E.suratensis* followed by *M. idella idella.*

Table 10.

Residues of HCH in different fish species occuring at Panangode area of the Vellayani lake

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.022	0.112	0.007	0.147	0.288
H. fossilis	0.024	BDL	0.012	BDL	0.036
M. idella idella	0.01	0.055	0.011	0.046	0.123
CD	NS	0.048	NS	0.048	0.048

BDL - Below Detectable Levels.

NS: Not significant

Gamma isomer was seen maximum in *H.fossilis* (0.012 ppm) followed by *M. idella idella* (0.011 ppm) and *E.suratensis* (0.007 ppm). Total HCH was maximum in *E. suratensis* (0.288 ppm) followed by *M. idella idella* (0.123 ppm) and *H. fossilis* sp (0.036 ppm). Statistically significant levels of beta, delta and total HCH were seen in *E suratensis* compared with that of other species of fishes.

03-04-01-04 Kakkamoola Market

All of the samples of fishes collected from Kakkamoola market contained detectable levels of all the four isomers of HCH in varying concentrations

Table 11.

Residues of HCH in different fish species occuring at Kakkamoola market of the Vellayani lake area

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E suratensis	0.01	0.08	0.01	0.07	0.17
H. fossilis	0.01	0.07	BDL	0.07	0.16
M. idella idella	0.01	0.07	BDL	0.07	0.15

Variations are not significant.

BDL - Below Detectable Level.

All the species of fish collected from Kakkamoola market contained 0.01 ppm each of alpha HCH. Beta HCH residue was maximum in *E. suratensis* (0.08 ppm) followed by *H. fossilis* and *M. idella idella* each with 0.07 ppm. Gamma HCH residue was present only in *E suratensis* the value being 0.01 ppm. Level of residues of the delta isomer was uniform in all the three species of the fish (0.07 ppm). Total HCH residues ranged from 0.15 ppm (*M. idella idella) to 0.17 ppm* (*E suratensis*), with an intermediate level of 0.16 ppm of total HCH in *H. fossilis* However none of the values were statistically significant.

03-04-02 SASTHAMKOTTA LAKE

The locations selected for fish sampling were Sasthamkotta, Karalimukku, and Bharanikkavu and the samples of fishes collected were *E.suratensis*, *H. fossilis* and *M. idella idella*. The samples of the same were also drawn from the market at Sasthamkotta.

03-04-02-01. Sasthamkotta

The predominant isomers within the fishes were beta and delta of HCH. (Table 12). When the alpha HCH residue varied from 0.01 to 0.012 ppm, gamma HCH varied from 0.005 to 0.009 ppm only. The maximum residues of alpha (0.012 ppm), beta (0.158), gamma (0.009), delta (0.112) and the total HCH (0.291) were detected in *E.suratensis*. This was followed by *M.idella idella*

Table 12.

Residues of HCH in different fish species occuring at Sasthamkotta location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.012	0.158	0.009	0.112	0.291
H . fossilis	0.01	0.063	0.007	0.053	0.132
M. idella idella	0.01	0.096	0.005	0.072	0.183

Variations not statistically significant.

where the values were very close excepting in the case of gamma isomer (0.005 ppm). Least level of residues of 0.01, 0.063, 0.007, 0.053 and 0.132 were detected in *H.fossilis* for the different isomers and the total HCH respectively.

03-04-02-02 Karalimukku

The residues of HCH detected in the samples of fishes collected from Karalimukku area of the Sasthamkotta lake were presented in table 13.

Table 13.

Residues of HCH in different fish species occuring at Karalimukku location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.011	0.166	0.011	0.119	0.306
H. fossilis	0.007	0.024	0.005	0.06	0.096
M. idella idella	0.013	0.121	BDL	0.051	0.186
CD	NS	0.048	NS	0.048	0.048

BDL-Below Detectable Level.

NS: Not significant

In this area also *E.suratensis* was containing the maximum residues of beta (0.166 ppm), gamma(0.011 ppm), delta (0.119 ppm) and total (0.306 ppm) HCH compared to other two species. The minimum residue levels of alpha (0.007 ppm), beta (0.024 ppm) and total HCH (0.096 ppm) were seen in *H.fossilis*. *M. idella idella* showed residues which were intermediary in general.

Statistically the beta, delta and total HCH were showing significant difference between the species. The beta isomer was significantly more in *E.suratensis* and *M. idella idella*. In the case of delta isomer the residue level was significantly more in *E.suratensis* only. The total HCH in *E.suratensis* and *M. idella idella* were significantly at higher levels compared to *H.fossilis*.

03-04-02-03. Bharanikkavu

Table 14 shows the residues of HCH in different species of fishes occuring at Bharnikkavu area of the Sasthamkotta lake.

Table 14.

Residues of HCH in different fish species occuring at Bharnikkavu location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.012	0.08	0.015	0.122	0.227
H. fossilis	0.011	0.094	0.006	0.089	0.179
M. idella idella	0.014	0.096	0.006	0.038	0.154
CD	NS	NS	NS	0.048	0.048

NS: Not statistically significant.

All the species were contaminated with varying levels of alpha, beta, gamma and delta isomers of HCH. The samples of *E.suratensis* contained maximum residues of gamma (0.015 ppm), delta (0.122 ppm) and total HCH (0.227 ppm) where as the alpha and beta isomers of HCH were maximum in the samples of *M. idella idella*; the residues being 0.014 ppm and 0.096 ppm respectively. The levels of residues in *H. fossilis* were alpha (0.011 ppm), beta (0.094 ppm), gamma (0.006 ppm) and delta (0.089 ppm) isomers of HCH. Statistically the samples of *E suratensis* contained significantly higher amounts of delta and total HCH compared with that of other fishes.

03-04-02-04. Sasthamkotta Market

The different fish species collected from Sasthamkotta market analysed for the residues of organochlorine insecticides revealed the presence of all the four isomers of HCH (Table 15.).

Table 15.

Residues of HCH in different fish species occuring at Sasthamkotta market in the Sasthamkotta lake area

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.01	0.11	0.01	0.13	0.27
H .fossilis	0.01	0.07	0.01	0.07	0.16
M. idella idella	0.01	0.08	BDL	0.06	0.15

Variations are not significant

BDL - Below Detectable Level.

Maximum residues of alpha (0.01 ppm), beta (0.11 ppm), gamma (0.01 ppm), delta(0.13 ppm) and total HCH (0.27 ppm) were seen in *E.suratensis* followed by *H.fossilis* , the values being 0.01, 0.07, 0.01, 0.07 and 0.16 ppm respectively. In *M. idella idella* the residues were lowest excepting beta (0.08 ppm).

03-04-03. KUTTANAD LAKE

Pulinkunnu, Monkompu and Kumarakom and the market at Kumarakom were selected for the collection of samples of the fish species. viz., *E.suratensis*, *H. fossilis* and *M. rosenbergii*.

03-04-03-01. Pulinkunnu

Table 16.

Residues of HCH in different fish species occuring at Pulinkunnu location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E.suratensis	0.004	0.042	0.003	0.034	0.083
H. fossilis	0.025	0.219	0.012	0.174	0.43
M. rosenbergii	0.005	0.048	BDL	0.052	0.105
CD	NS	0.048	NS	0.048	0.048

BDL - Below Detectable Level.

NS: Not significant.

The maximum level of all the isomers were detected in *H. fossilis*, the residue levels being 0.025, 0.219, 0.012, 0.174 and 0.43 ppm respectively for alpha, beta, gamma, delta and total HCH. *M.rosenbergii* was showing residues to the tune of 0.005 ppm for alpha, 0.048 ppm for beta, 0.052 ppm for delta and 0.105 ppm for total HCH and there was no detectable levels of gamma HCH. The minimum levels of 0.004, 0.042, 0.003, 0.034 and 0.083 ppm of alpha, beta, gamma, delta and total HCH were seen in *E.suratensis*. Significantly higher amounts of beta, delta and total HCH were detected in the samples of *H. fossilis* compared to other species.

03-04-03-02. Monkompu

Table17.

Residues of HCH in different fish species occuring at Monkompu location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.004	0.028	0.003	0.045	0.08
H. fossilis	0.018	0.178	0.012	0.158	0.366
M. rosenbergii	0.007	0.091	BDL	0.086	0.184
CD	NS	0.048	NS	0.048	0.048

BDL - Below Detectable Level.

NS - Not significant

As in Pulinkunnu, the highest residue of all the isomers and total HCH were detected in *H.fossilis*; the values were, for alpha 0.018 ppm, for beta 0.178 ppm, for gamma 0.012 ppm, delta 0.158 ppm and total 0.366 ppm, all of which except alpha and gamma were significantly higher when compared to other two species.

In *M.rosenbergii* the residues were ranking next in alpha (0.007), beta (0.091), delta (0.086) and total HCH (0.184); the gamma HCH was below detectable levels. The least residues were shown by *E suratensis* regarding all the isomers.

03-04-03-03. Kumarakom

The residues of organochlorine compounds found in the samples of fishes collected from Kumarakom are presented in Table 18.

Table 18.

Residues of HCH in different fish species occuring at Kumarakom location.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E. suratensis	0.018	0.095	0.006	0.063	0.183
H. fossilis	0.021	0.202	0.01	0.082	0.315
M. rosenbergii	0.005	0.051	0.005	0.049	0.110
CD	NS	0.049	NS	NS	0.048

NS: Not significant

H. fossilis was showing maximum residues of total HCH (0.315 ppm) and the isomer (alpha 0.021 ppm, beta 0.202 ppm, gamma 0.01 ppm and delta 0.082 ppm). The beta isomer and the total HCH were significantly higher in *H.fossilis* when their residue levels were compared to other two fish species. In *E.suratensis* the residues were 0.018, 0.095, 0.006, 0.063 and 0.183 for alpha, beta, gamma, delta and total HCH respectively. *M. rosenbergii* was showing minimum residues at Kumarakom compared to other two fish species.

03-04-03-04. Kumrakom Market

All the samples of *E.suratensis*, *H. fossilis* and *M. rosenbergii* were contaminated with varying levels of HCH residues (Table 19)

Table 19.

Residues of HCH in different fish species occuring at Kumarakom market of Kumarakom lake area.

Fish Species	Residues of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E.suratensis	0.02	0.07	0.01	0.08	0.18
H. fossilis	0.02	0.20	BDL	0.14	0.37
M. rosenbergii	0.01	0.11	0.02	0.07	0.20

BDL - Below Detectable Levels

NS - Not Significant

The market samples of *H.fossilis* was having the maximum levels of total HCH (0.37 ppm), and the isomers (alpha 0.02 ppm, beta 0.2 ppm and delta 0.14 ppm) except gamma where it was below detectable level. In *M.rosenbergii* the residues were intermediate for beta (0.11 ppm) and total HCH (0.2 ppm) and maximum for gamma (0.02 ppm); in *E.suratensis* excepting for alpha (0.02 ppm), delta (0.08 ppm) and gamma (0.01 ppm), the other isomer (beta) and total HCH were minimum compared to other two species of fishes in the market. However there was no statistical significance in the different levels of the residues of HCH detected in the different species of fishes collected from the market.

03-05. VARIATIONS IN RESIDUE LEVELS IN THE DIFFERENT AREAS COVERED IN THE SURVEY

For comparing the levels of insecticide pollution in different ecosystems covered in the survey data relating to the residues in different components of the ecosystem were pooled and analysed. The mean values and results of statistical analysis are presented below.

03-05-01 RESIDUES IN WATER

Data presented in Table 20 revealed that the total content of HCH isomers in water was highest in Kuttanadu(5.75 ppb) and it was followed by the residue content in the samples collected from Sasthamkotta(2.64 ppb), the variations between the two being statistically significant. The residue content in Vellayani samples was 0.53 ppb only and it was significantly lower than those of the other two lakes.

Table 20.

Residues of HCH in water collected from different ecosystems.

Ecosystem	Residue of HCH (in ppb)				
	Alpha	Beta	Gamma	Delta	Total
Vellayani	0.29	BDL	0.25	BDL	0.53
Sasthamkotta	0.18	1.05	0.18	1.22	2.64
Kuttanadu	0.21	3.40	0.16	2.00	5.75
CD	NS	NS	NS	NS	2.09

BDL - Below Detectable Levels.

NS: Not significant

Residues of gamma isomer of HCH was highest in samples collected from Vellayani(0.25 ppb) and it was followed by Sasthamkotta and Kuttanadu(0.18 and 0.16 ppb respectively). These variations were not significant statistically.

Beta and delta isomers of HCH were below detectable levels in water samples from Vellayani while in Sasthamkotta and Kuttanadu the contents were 1.05/1.22 and 3.4/2.0 for beta/ delta isomers respectively.

The alpha isomer content was highest at Vellayani (0.29 ppb) followed by Kuttanadu and Sasthamkotta(0.21 and 0.18 ppb respectively). The variations in the data were not statistically significant.

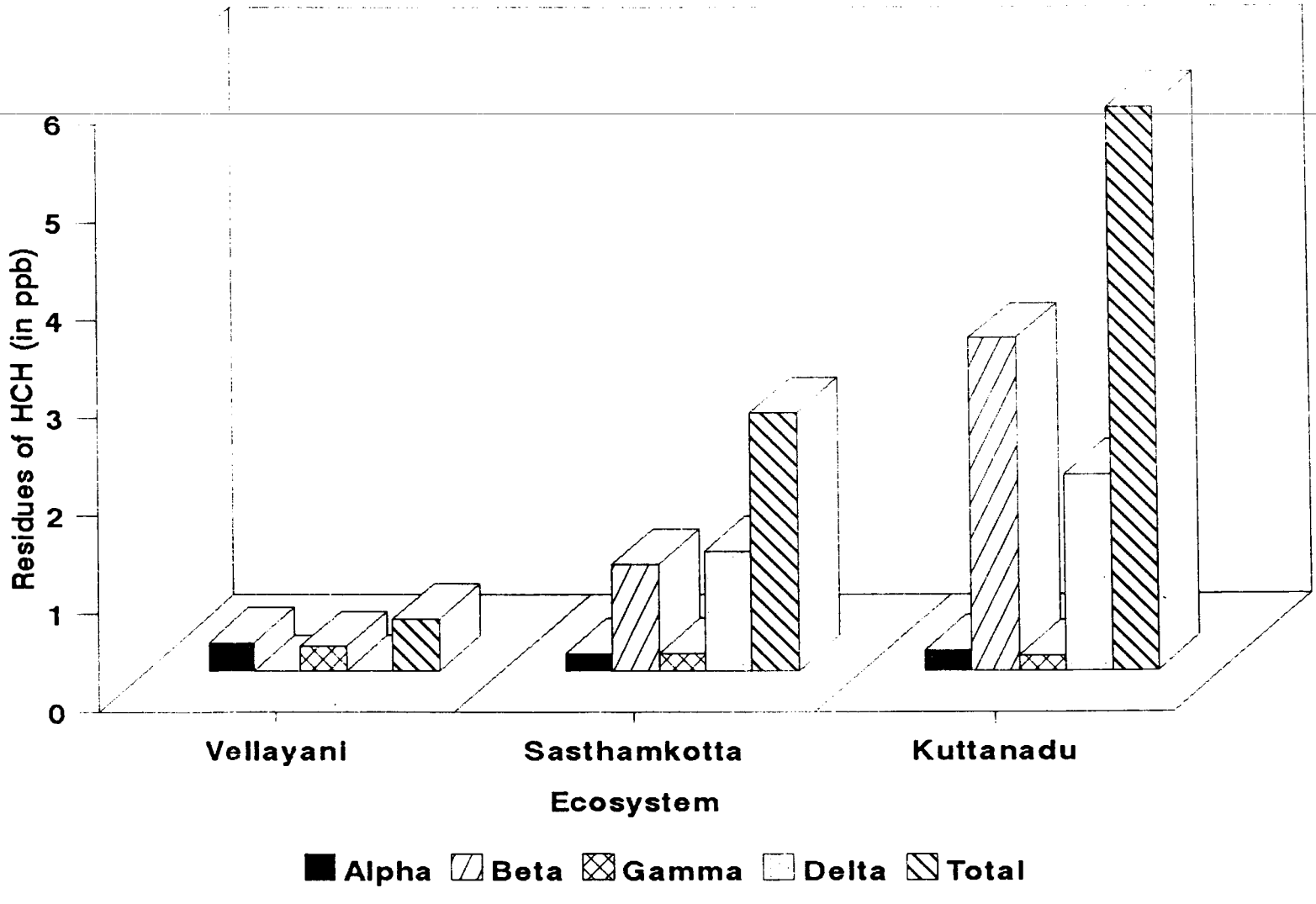


Fig. 1. Residues of HCH in water

03-05-02. RESIDUES IN SEDIMENTS

Data presented in Table 21 showed that total HCH isomers in samples collected from Kuttanadu and Vellayani (2.71 and 2.44 ppm) were on par and significantly higher than those of the sediment samples from Sasthamkotta (0.56 ppm).

Table 21.

Residues of HCH in sediment collected from different ecosystems.

Ecosystem	Residue of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
Vellayani	0.11	1.14	0.08	1.12	2.44
Sasthamkotta	0.14	0.19	0.03	0.19	0.56
Kuttanadu	0.17	1.41	0.09	1.04	2.71
CD	NS	NS	NS	0.59	1.74

NS: Not significant

Delta isomers in samples from Kuttanadu and Vellayani (1.04 and 1.12 ppm respectively) were also on par and significantly higher than that of Sasthamkotta samples (0.19 ppm)

Gamma, beta and alpha isomer content which ranged from 0.03 to 0.09, 0.19 to 1.41, 0.11 to 0.17 ppm respectively did not show statistically significant variations.

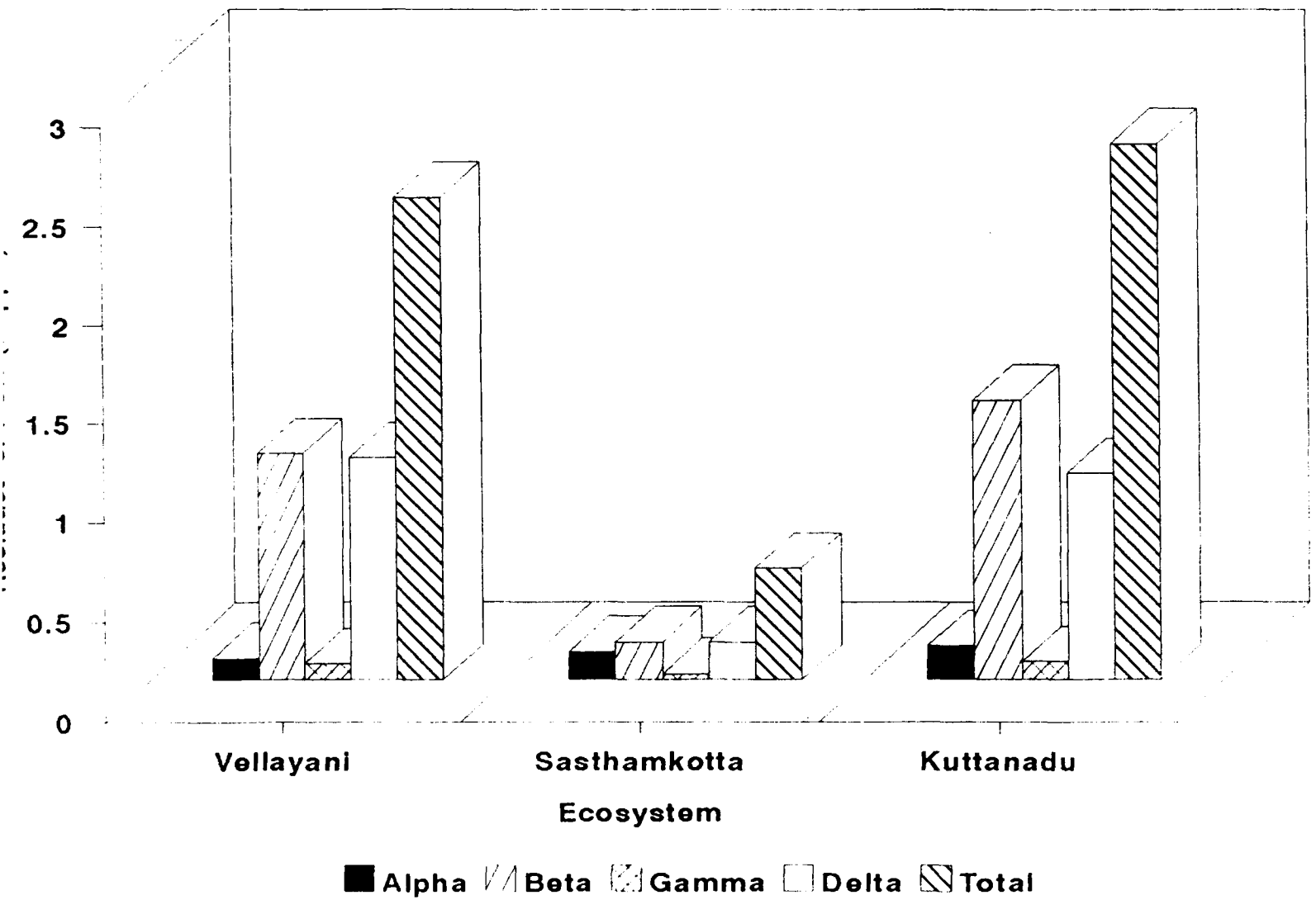


Fig. 2. Residues of HCH in sediment

03-05-03. RESIDUES IN FISHES

The relevent data and results of statistical analysis are presented in Table 22. *E. suratensis* collected from Sasthamkotta showed significantly higher content of delta HCH and total of HCH isomers (0.117 and 0. 275 ppm respectively) with those collected from Vellayani and Kuttanadu which were on par and significantly lower. Alpha isomer ranging from 0.009 to 0.140, beta isomer ranging from 0.055 to 0.134 and gamma isomer ranging from 0.004 to 0.011 ppm did not show significant vaariation.

In *H. fossilis*, alpha and beta isomers as well as total HCH (0.02,0.20 and 0.370 ppm respectively) were higher in samples collected from Kuttanadu while the residues in fishes collected from Sasthamkotta and Vellayani , the content of alpha and beta isomers were on par and significantly lower than these from Kuttanadu . Content of gamma isomer in fishes from the three locations ranging from 0.006-0.011 and delta isomer ranging from BDL to 0.138 ppm did not show statistically significant variations.

Residues of alpha HCH was significantly higher in samples of prawns collected from Sasthamkotta (0.012 ppm) while those from Vellayani and Kuttanadu contained significantly lower levels (0.009 and 0.006 respectively) and the latter were on par . Beta isomer ranging from 0.063 to 0.105, gamma HCH ranging from 0.002 to 0.008, delta isomer ranging from 0.054 to 0.087, and the total HCH content ranging from 0.133 to 0.193 ppm did not show statistically significant variations.

Table 21

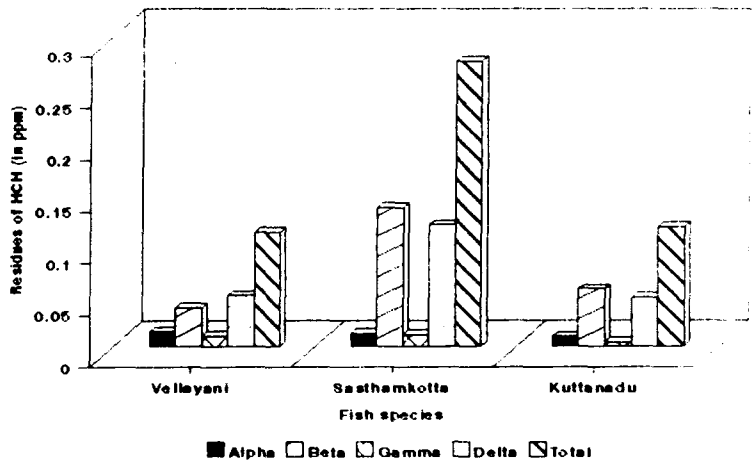
Mean residues of the isomers of HCH in different species of fishes collected from the different ecosystems of Kerala.

Fish/Ecosystem	Residue of HCH (in ppm)				
	Alpha	Beta	Gamma	Delta	Total
E suratensis					
Vellayani	0.014	0.037	0.010	0.049	0.110
Sasthamkotta	0.012	0.134	0.011	0.117	0.275
Kuttanad	0.009	0.055	0.004	0.047	0.115
Mean	0.012	0.075	0.008	0.071	0.167
CD	NS	NS	NS	0.057	0.124
H fossilis					
Vellayani	0.016	BDL	0.008	BDL	0.024
Sasthamkotta	0.009	0.060	0.006	0.067	0.142
Kuttanad	0.020	0.200	0.011	0.138	0.370
Mean	0.015	0.086	0.008	0.068	0.178
CD	0.006	0.066	NS	NS	0.087
Macrobrachium spp					
Vellayani	0.009	0.089	0.008	0.087	0.193
Sasthamkotta	0.012	0.105	0.004	0.054	0.174
Kuttanad	0.006	0.063	0.002	0.062	0.133
Mean	0.009	0.086	0.004	0.068	0.166
CD	0.003	NS	NS	NS	NS

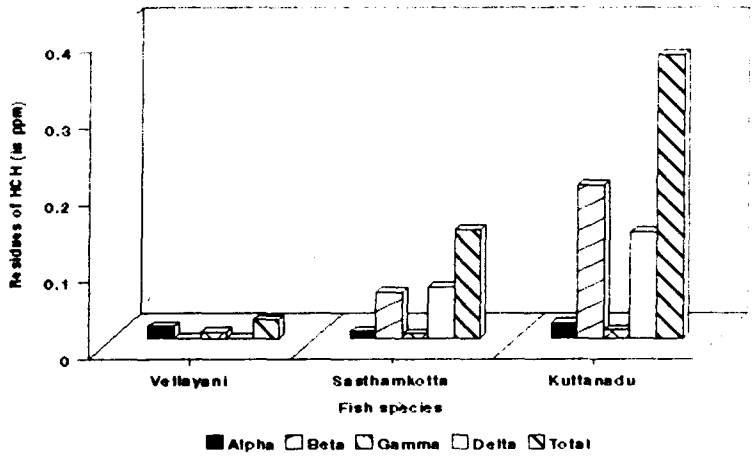
BDL - Below Detectable Level.

NS: Not significant

E. suratensis



H. fossilis



Macrobachium spp.

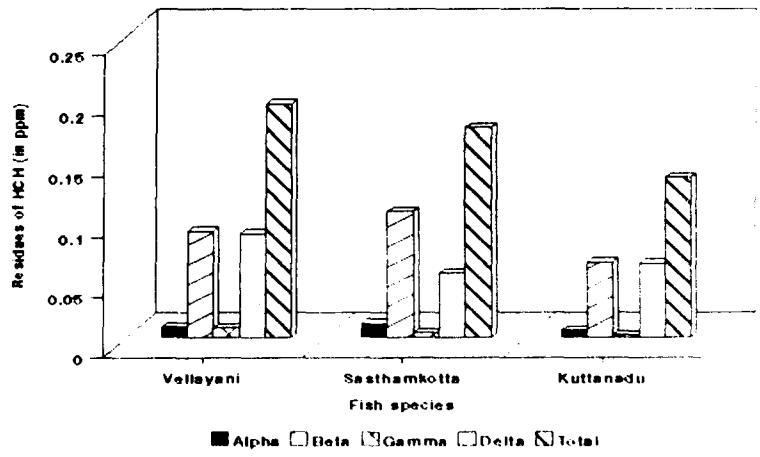


Fig. 3. Residues of HCH in fishes (ppm)

DISCUSSION

04. DISCUSSION

The unique system of dewatering parts of the inland water bodies and raising 'punja rice crop', particularly with high yielding varieties necessitating heavy insecticidal cover, and the flooding of these cultivated areas contiguous with the rest of the water bodies during rains renders the ecosystem prone to very serious insecticidal pollution. Two such vast ecosystems are the 'Kuttanad region' and the 'Kole lands' of South and Central parts of the state. The fresh water lakes at Vellayani and 'Sasthamkotta' have slightly different ecosystems. Vellayani also has the 'punja type' of the rice cultivation as in Kuttanad and Kole lands, but here conventional varieties, with less insecticide input, are grown and a number of pockets with vegetable cultivation also exists along the uplands adjascent to the lake where the insecticidal input is quite heavy and hence chances for water contamination through surface run off prevails. 'Sasthamkotta' lake represent the tract where rice crop with conventional varieties of rice alone are grown and hence having less chances of insecticidal contamination. In the present investigations the two fresh water lakes and one pocket in lower Kuttanad were chosen as typical areas covering the three types of ecosystems.

Further it is known that the insecticides reaching the water bodies from various sources remain in a dynamic system. The least quantum of the pollutant remain in water and the sediments become a 'sink' for the residues in due course. The residues in water and sediments get involved in the food chain finally reaching the fishes in the ecosystem which form a direct source of pesticide hazard to human health. The present studies were designed with a view to analysing the levels of pesticide content in these three components of the ecosystem.

04.01 Residues of organochlorine insecticides detected in the ecosystems

The results presented in para 3.01.01 showed that among the organochlorine pesticides DDT, endosulfan and HCH which were being used extensively in Kuttanad and Kole lands till the end of the last decade residues of HCH alone could be detected in the samples collected now. In survey conducted by an Indo-Norvegion team of Scientists in 1989 the entire Kuttanad belt was reported to contain significant levels of DDT, HCH and endosulfan residues. Though DDT was already excluded from the pesticides recommended for paddy pest control in the state the existence of the high level of the residues of the insecticide and its metabolites showed continued use of the insecticide in the ecosystem then. The total absence of DDT and endosulfan residues and their metabolities in the ecosystem indicated that from among the chlorinated insecticides now available in the market HCH alone is being used for rice pest control in the three regions covered in the survey. Sunil kumar *et al* (1994) who investigated the insecticide content in the water and sediment samples from different regions of Kuttanad also found that isomers of HCH were the only chlorinated insecticide residues present in the region. The absence of DDT residues and its metabolites in the ecosystem further showed that the insecticide pollutants originated exclusively from the plant protection measures adopted in the area, since DDT is still being used extensively for the malaria control programme in the state.

04.02. Insecticide residues in water

The exteut of HCH contamination of the water component of the three ecosystems are presented in para 03-02-01 to 03-02-03. The residue content did not show significant variations among the different locations in each area. The total HCH content ranged from 0.44 to 0.69,

1.3 to 4.26, and 4.43 to 6.66 ppb in samples collected from Vellayani, Sasthamkotta and Kuttanad respectively. Lack of significant variations among the different locations in each area showed that the water in each ecosystem was uniformly polluted with the insecticide residues inspite of the variations in the pattern of cultivation and plant protection measures adopted in the regions.

Among the isomers of HCH only gamma and alpha isomers were detected in the Vellayani area and these were present almost in equal proportions. At Sasthamkotta all the four isomers were present and beta and delta isomer content varied from 38.2 to 59.2 and 26.8 to 50.4 per cent respectively, while the gamma and alpha isomers varied from the 3.52 to 14.8 and 4.2 to 7.74 per cent respectively. In samples from Kuttanad the percentage of delta, beta, gamma and alpha isomers varied from 31.6 to 36.2, 56.8 to 62.0, 2.8 to 3.0 and 3.3 to 4.2 respectively. Such detailed studies on the four isomers of HCH in water has been done for the first time in the state.

Water contamination in the three ecosystems showed significant variations in pooled data as seen from the results presented in para 03-05-01. The highest pollution was in Kuttanad (5.75 ppb) and it was followed by Sasthamkotta (2.64 ppb) and Vellyani (0.53 ppb). Water contamination in the fresh water ecosystem is being studied for the first time. The residue level showed decline from 0.8 ppb (alpha + gamma isomers) reported in 1989 by the Indo-Norvegian team of scientists. Sunilkumar *et al* (1994) could detect a maximum of 0.274 ppt (alpha + gamma isomers) only in their samples collected from the area. The results indicated a reduced rate of HCH use in the area in recent years.

The residues reported from Punjab (0.9 ppb - Kalra and Chawla, 1981) Delhi / Kanpur / Calcutta (0.003 to 0.116 ppb - Thakkar and Pande, 1984) Lucknow / Sri Nagar (0.0025 to

0.0735 ppb, Kapalia *et al.*,1988). Central Westcoast of India (0.0002 to 0.0094 ppb - Sarkar and Gupta, 1989) Tamil Nadu (trace - Ramesh *et al.*, 1990) Mahala water reservoir (trace - Bakre *et al.*,1990) where lower than levels found in Kerala and those from Mysore (127 to 2360 ppb - Raju *et al.*,1982) Rajasthan (0.05 to 9.29 ppb - Kumar *et al.*,1988), Indore / Ujjain / Nagda (49.02 to 2720 ppb - Kulshrestha *et al.*,1989), Madras (6 to 8255 ppb - Sivaswami *et al.*,1989), Bhopal (1516 to 15580 ppb - Dikshit *et al.*,1990) and Ganga river (1 to 2 ppb - Halder *et al.*,1990) were higher than the levels found in the state. Above reports showed that the water pollution in Kuttanad is heavier than six locations, slightly less than two locations and significantly less than 4 locations reported from different parts of India.

No Acceptable Daily Intake has been recommended by WHO and FAO for HCH due to the variations in the isomer constituents crude formulations of the insecticides (Gupta *et al.*, 1982). But 3 ppb has been fixed as Maximum Residue Level of lindane (gamma HCH) in water used for drinking purpose by WHO (1984). According to the EPA - water quality `Criterion' fixed for lindane ie., the concentration of a pestcide in water that will protect an organism, an organism community or prescribed water use or quality with an adequate degree of safety is 0.01 ppb. (Takroo and Ray, 1987). According to these norms the residue of lindane detected in any of the region investigated has not exceeded the limit fixed for the drinking purpose. But at all the locations and regions the limit of the `water quality criteria of EPA' has been exceeded.

Among the four isomers present, gamma isomer (10 to 18 % of HCH) has high acute but low chronic and cumulative toxicities, alpha isomer (55 to 70 % of HCH) has low acute, chronic and cumulative toxicity, beta isomer (5 to 14 % of HCH) has low acute but high chronic and cumulative toxicities and delta isomer (6 to 8 % HCH) has low acute and chronic toxicities but

cause irritance to mucous membrane (Martin, 1968). Beta isomer is considered carcinogenic also (Agnihortri, 1993). Obviously as a chronic toxicant with carcinogenecity it must be rated as more hazardous than gamma isomer. At Sasthamkotta and Kuttanad regions the beta isomer content in water was high though the levels of gamma isomer remained within the MRL fixed by WHO. Thus the quality of water in the two regions do not appear to be safe for drinking purposes eventhough the level of lindane was much below the maximum limit fixed by WHO.

04.03. Isomers of HCH in the sediments in different ecosystems

The residues present in the different ecosystems are presented in para 03-03-01 to 03-03-03. Total HCH residue ranging from 2.06 to 2.80 ppm at Vellayani and from 0.35 to 0.69 ppm at Sasthamkotta did not show significant variations among the three locations in each area. But at Kuttanad the residues at Monkombu (5.33 ppm) were significantly higher than those of Kumrakam (1.75 ppm) and Pulinkunnu (1.73 ppm), the latter two being on par.

In the pooled analysis of data comparing the three regions (para 03-05-02) the mean residue levels at Kuttanad (2.71 ppm) and Vellayani (2.44 ppm) were found on par and significantly higher than that of Sasthamkotta (0.56 ppm). Quantity of insecticide pollutants of the sediments in the two fresh water ecosystems in the state was assessed for the first time. In Kuttanad the Indo-Norvegian team of scientists recorded upto 0.02 ppm of alpha isomer and 02 ppm of gamma isomer and Sunilkumar *et al* (1994) estimated 0.04 ppt of alpha HCH and 0.03 ppt of gamma HCH. Sivaswami (1989) reported 0.0003 to 10.731 ppm gamma HCH from Madras. Beta and delta isomers were detected from the sediments in India. Although incidence of residues in sediments, the persistence and degradation have been documented from western

countries, information available from Indian water bodies is very meagre. (Kulshrestha, 1991). Hirano and Katada (1975) detected traces of alpha and gamma HCH in Japan. Shumei *et al* (1986) found 0.0015 to 0.027 ppm HCH occuring in the sediments at different locations of Xiamen harbour. Hume *et al* (1989) reported traces of gamma isomer in Newzealand.

When HCH content of water and sediments in different ecosystems were examined together it was found that the residue in water was low and residue in sediment was high in Vellayani ecosystem and the reverse was the situation at Sasthamkotta ecosystem. Further beta and delta isomers were absent in the water of Vellayani lake while the sediments in the area contained 46.7 percent and 45.9 percent of total residue as beta and delta isomers. In Sasthamkotta region in the sediments 33.9 percent of the total residue were available as beta isomer and 33.9 percent as delta isomer while water also contained both the isomers. The absence of the beta and delta isomers in water with a higher proportion of the residues of two isomers in the sediment at Vellayani and a lower proportion of isomers in sediment with certain percent in water component also at Sasthamkotta lead to the conclusion that the lower residues in the earlier situation might have occured due to settlement of residue from water to sediments.

The quantity of residue of the alpha, beta, gamma, delta isomers of HCH and their totals in the sediments at Vellayani were 379, 0, 320, 0, and 4603 times higher than those of the coressponding residues in water respectively, while corresponding values for Sasthamkotta and Kuttanad were 777, 174, 166, 155, 212 and 809, 414, 562, 520, 471 times respectively. The settlement of the pesticides, entering an aquatic system to the lower layers leading to its gradual several fold accumulation in the sediments have been reported by many of the earlier workers. (Bailey and Hannum, 1971; Konar, 1971; Hirano and Katada, 1975). The sediments were seen as an effective 'sink' for pesticide pollutants in all the ecosystem.

Possible adverse effects of insecticide pollution of water bodies will be the additive effect of the pollutant remaining dissolved or suspended in water and the residues accumulating in the sediments. Total HCH residues of Kuttanad, Vellayani and Sasthamkotta regions were 2716, 2441 and 563 ppb respectively. Obviously on pollution criterion three ecosystems can be arranged in the same descending order and it is in broad agreement with the insecticide input in the area relating to prevalent agricultural pattern in each region.

04.04 Insecticide residues in fish fauna of the eco systems

The fishes are recognised as excellent indicators of pesticide residues in the aquatic environment. Being at the top of the aquatic food chain fish contaminated with pesticides do have a direct bearing on pesticide levels in human body. Two species of fishes *Eteroplus suratensis* and *Heteropneustes fossilis* and the predominant species of prawns available in each ecosystem (*Macrobrachium idella idella* at Vellayani and Sasthamkotta and *M. rosenbergii* at Kuttanad) were chosen for monitoring the insecticide contamination in different ecosytem.

Results presented in para 03-04-01-01 to 03-04-03-04 showed that all the species chosen for the study contained varying levels of HCH isoiners. In the fresh water ecosystem *E. suratensis* had the highest residue content, the range being 0.014 to 0.288, and 0.227 to 0.306 ppm at Vellayani and Sasthamkotta respectively. In prawns the ranges were 0.123 to 0.247 and 0.154 to 0.186 ppm in Vellayani and Sasthamkotta ecosystem respectively. In *H. fossilis* the content varied from 0.014 to 0.036 and 0.096 to 0.179 at Vellayani and Sasthamkotta respectively. On the basis of the residue content the three species can be ranked in the following descending order *E. suratensis, M. idella idella* and *H. fossilis*, the latter two were statistically on par in some of the locations.

The residue content in the three species collected from different locations in the two regions also showed significant variations. *E. suratensis* had significantly higher residues than the other two species at Kakkamoola and Panangode, while the values at Vellayani did not show significant variations. In Sasthamkotta ecosystem *E. suratensis* collected from Karalimukku and Bharanikavu showed significantly higher residue content when compared to the other two species while data from Sasthamkotta did not show statistically significant variations. The residues in fish species and the crustaceans had no direct or indirect correlation with residue content in water or sediment.

It is interesting to note that the residuesof beta and delta isomers were not detected in *H. fossilis* from all locations from Vellayani while in *E. suratensis* the isomers were not present in two of the three locations. But the prawns collected from all the locations had residues of all the four isomers of HCH. These isomers were absent in the water constituent of the ecosystem while in sedeiments both isomers were present. The data thus indicated that the fishes absorb the residues largely from water while the prawns imbibed the same from both water and sediments.

Regarding the Kuttanad ecosystem the relative positon of the three species with reference to the residue content showed a different picture. *H. fossilis* with residues ranging from 0.315 to 0.43 ppm ranked high and it was followed by the prawn *M. rosenbergii* (0.105 to 0.184 ppm) and *E. suratensis* 0.08 to 0.183 ppm. While these variations were statistically significant in fishes collected from Pulinkunnu and Monkompu, variations were not significant in samples collected from Kumarakom.

The total residue content in market samplesof fishes and prawn varied from 0.15 to 0.17, 0.15 to 0.27 and 0.18 to 0.37 at Vellayani, Sasthamkotta and Kuttanadu respectively and these variations and the variations in the content of different isomers of HCH did not show significance in statistical analysis.

As shown in para 03-05-03 *E. suratensis* collected from Sasthamkotta showed significantlly higher content of HCH residues than in those collected from Vellayani and Kuttanadu, the latter two being on par statistically. *H. fossilis* collected from Kuttanad showed significantly higher content of HCH residue than those collected from Sasthamkotta and Vellayani. Data relating to the residue content in the two species of prawns collected from the threee regions did not show significant variations. These variations also were not correlated with residue levels in water or sediment or both. Statistical analysis of the data also revealed the lack of significant correlations between the levels of pollutant in the surroundings and those of the tissues of the organisms. Fishes and the crustaceans chosen in the studies indicated the presence of the pollutants in the ecosystem though the quantitative variations were not reflected in the same; obviously the contamination levels.

Another important point emerging from the studies is the presence of all the four isomers of HCH in all the animal species chosen for the investigations. The major constituents of HCH viz., alpha and gamma isomers constitute only three to four per cent of the total residues, the former being slightly more in proportion. Among beta and delta isomers which constitute 96 to 97 percent of the total residue, beta isomer was slightly higher in proportion. The result showed the higher accumulation of beta (44.9 to 51.8 %) and delta (38.2 to 42.5 %) isomers in the tissues of aquatic organisms.

Residues of the gamma isomers of HCH was reported from fishes in Ganga waters in India as early as 1985 by Joshi, the content being 0.048 to 0.210 ppm. Subsequent reports from Lucknow (0.004 - 0.410 ppm - Kaphalia *et al*, 1986), Indore / Ujjain / Nagda-Kota (Non-dectactable levels to 0.00254 / 0.0084 / 0.0083 ppm - Kulshrestha, *et al.*, 1989), Cochin, Kerala (0.0023 - 0.2 ppm - Radhakrishnan and Antony, 1989) and Hooghly (0.004 to 0.36 ppm - Kulshrestha 1991) also showed that the levels of contaminations of fishes in Kerala was higher than those reported from many parts of India. Reports from Punjab (0.031 to 0.247 ppm - Kalra and Chawla, 1981), Madhya Pradesh (007 - 1.244 ppm - Srivastava, 1987) and Indore (0.0043 to 1.008 ppm of gamma isomer - Sharma and Dhakkad, 1995) exceeded the levels found in Kerala. Residues of alpha HCH reported from countries outside India ranges from trace to 0.027 ppm only. (Cadwallader, 1978; Martin and Hartman, 1985; Celeste and Caceres. 1988; Muir, *et al*, 1990, Ramotsa, *et al*, 1990).

As in the case of water pollution maximum residue limits of HCH or its isomers have not been fixed in fishes and other aquatic organisms. But the active level (MRL) fixed for DDT is 5 ppm. (FDA, 1977) and residues of HCH is accepted as less hazardous than DDT to human health. In the light of the above, the residue content of HCH isomers observed in the different aquatic organisms are far below the hazard levels. But the higher proportion of beta isomer of HCH which is known as chronic toxicant and a carcinogenic subtance is alarming.

Thus the fresh water and backwater ecosystems of Kerala were found to be polluted with isomers of HCH to varying levels. Kuttanad region was seen most contaminated and it was followed by Vellayani and Sasthamkotta. The source of contamination appears to be from the plant protection measures adopted in relation to the varying systems of agriculture prevalent in

the three ecosystems. The aquatic fauna as seen in fishes and crustacean chosen for the studies have acquired the residues of the isomers of HCH at significantly higher levels than the levels reported from different areas in India and outside countries. Though the present level of toxicant remain below hazardous levels the predominence of beta isomer in the residue content which is definitely known as a chronic toxicant and a carcinogen is a matter for great concern. As seen from the total absence of DDT and endosulfan residues in the ecosystem subsequent to the discontinuation of the use of the insecticide for agricultural purposes withdrawl of HCH from agrochemicals is likely to reduce or eliminate the hazards of organo chlorine pesticide residues in the inland water bodies of Kerala. However, the above observations are based on an one time assessment of pesticide residues in the ecosystem and for conclusive results repeated and more extensive monitoring of the residues of insecticides in different components of ecosystem may be essential. The prevalence of pollution problem in the aquatic environment of the different ecosystems in the state has been conclusively identified through the present investigations.

SUMMARY

SUMMARY

The pesticide contamination in three different ecosystems in Kerala represented by two fresh water lakes at Vellayani and Sasthamkotta and one area of lower Kuttanad was assessed with a view to identify the existence and content of insecticide pollution problem in the areas. Residues in the three components of the ecosystem viz., water, sediments and fishes were assessed. Organochlorine insecticides alone were included in the studies, since, they are much more stable and hazardous than the organophosphates, carbamates and pyrethroids commonly used in the region. Among DDT, endosulfan and HCH residues estimated, isomers of HCH alone could be detected in the samples.

Total HCH residues in water samples collected from different locations in Vellayani, Sasthamkotta and Kuttanad regions ranged between 0.44 and 0.69, 1.30 and 4.26, 4.43 and 6.66 ppb respectively. The data did not show statistically significant variations among the different locations in each area thus showing that the entire water constituent of each ecosystem was uniformly polluted.

Pooled analysis of the data from different regions showed significant variations in the insecticide pollution of the different ecosystems, the mean HCH residues at Kuttanad, Sasthamkotta and Vellayani being 5.75, 2.64 and 0.53 ppb respectively. The level of water pollution now found in Kerala is higher than the levels reported from majority of earlier reports from different parts of the country. On the basis of gamma isomer content in water for which the MRL has been fixed as 3 ppb for drinking purpose the pollution level in Kerala has not yet

reached a critical stage. But the residues in water in Sasthamkotta and Kuttanad regions far exceeded the `water quality criterion' of 0.01 ppb fixed EPA.

The residues (total) in the sediments at Vellayani (from 2.06 to 2.80 ppm) and Sasthamkotta (0.35 to 0.69 ppm) did not show statistically significant variations among different locations in each area. But at Kuttanad, residues at Moncompu (5.43 ppm) was significantly higher than those of Kumarakom (0.97 ppm) and Pulinkunnu (1.73 ppm). Pooled analysis of the data for comparing the three ecosystems Kuttanad (mean residue 2.71 ppm) and Vellayani (2.44 ppm) came on par and significantly more polluted than Sasthamkotta (0.56 ppm).

When distribution of residues in water and sediments in Vellayani and Sasthamkotta ecosystems were examined together the absence of beta and delta isomers in water at Vellayani with a comparatively high proportion of isomers in sediments and lower proportion of the isomers in sedimens combined with the presence of the same in the water also at Sasthamkotta revealed that the apparent anomaly arose due to a faster settlement of the residues from water to sediment at Vellayani.

The residues of alpha, beta, gamma and delta isomers in sediments were 379, 0, 320, 0, 4603 times more than the corresponding residues in water at Vellayani while corresponding levels at Sasthamkotta and Kuttanad areas were 777, 174, 166, 155, 212 and 809, 414, 563, 520, 471 times respectively. This indicated that the sediment in all the regions had become a `sink' for the insecticide pollutants in water bodies over the years.

The total HCH residues in water and sediments taken together for the three regions were 2716, 2441 and 563 ppb respectively and on pollution criteria the three ecosystems can be arranged as Kuttanad, Vellayani and Sasthamkotta.

The fishes are known as good indicators of insecticide pollution of an aquatic system. The residues in two species of fishes viz., *Eteroplus suratensis* and *Heteropneustes fossilis* and one species of prawn (*Macrobrachium rosenbergii* at Kuttanad and *M. idella idella* at Sasthamkotta and Vellayani.) were analysed for insecticide residues. In fresh water ecosystem *E. suratensis* had significantly higher residue (0.014 to 0.306 ppm) and it was followed prawns (0.123 to 0.247 ppm) and *H. fossilis* (0.014 to 0.179 ppm) the latter two being on par in some of the locations. Residue content in fishes collected from different locations in each region also showed significant variations. In Kuttanad region *H. fossilis* (0.315 to 0.430 ppm HCH) was most contaminated and it was followed by *M. rosenbergii* (0.105 to 0.184 ppm) and *E. suratensis* (0.080 to 0.183 ppm).

Absence of beta and delta isomers in fishes in Vellayani where the water did not have the residue and the presence of both residues in prawns indicated that the former absorbed pollutants largely from water while the latter derived the same from both water and sediments. Statistical analysis of the data obtained from different regions and locations did not reveal any significant correlation between the residue content in the tissues of the fishes and crustaceana examined and the residue levels in water, soil or both. Thus the animal fauna indicated existence of the pollutants in the ecosystem but not the quantity of the same. The market samples of fishes and prawns collected from different regions showed varying levels of isomers of HCH (total 0.15 to 0.37 ppm) but the variations were not statistically significant.

The residues detected in different species of aquatic animals chosen in different ecosystem appears to be below hazardous levels. But the high proportion of beta isomer of HCH (44.9 to 51.8 % of the total residue) which is known as a chronic toxicant and a carcinogen is alarming.

Prevalence of a serious insecticide pollution problem in the backwater and fresh water ecosystems of Kerala has been conclusively identified and the possibilities of reducing or eliminating the residue hazards from organochlorine insecticides in the above environment by avoiding the use of HCH for agriculture purposes is strongly indicated.

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* *Originals not seen*

ABSTRACT

Residues of organochlorine insecticides in three different ecosystems in Kerala viz., the fresh water ecosytems at Vellayani and Sasthamkotta and backwater region in lower Kuttanad were assessed. Residues in the three components of the ecosystem viz., water, sediment and fishes were estimated. Following were the salient findings.

Among organochlorine insecticides (DDT, endosulfan, HCH widely used) isomers of HCH alone were detected in the samples.

The water in all the different regions were found polluted with varying levels of isomers of HCH. The content at different locations in each area did not show statistically significant variation, thus indicating a wide spreading of insecticide contaminants reaching the water bodies.

The pooled analysis of the data revealed that among the three ecosystems, water in Kuttanad was most polluted and it was followed by Sasthamkotta and Vellayani. The level of pollution is comparable with majority of levels reported from other parts of India so far.

The levels of gamma isomer for which 3 ppb has been fixed as the Maximum Residue Limit for drinking purposes, did not reach hazardous levels. But the content of these toxicant in all situations exceeded the 'safe criterion' of 0.01 ppb fixed by EPA.

Regarding the residues in sediments statistically significant variations did not exist among the locations at Vellayani and Sasthamkotta while at Kuttanad, Moncompu was more significantly polluted than Kumarakom and Pulinkunnu.

In pooled analysis of the data Kuttanad and Vellayani were seen on par and more polluted than Sasthamkotta.

Taking the residues in water and sediments together the three ecosystems could be ranked in the following descending order of pollution : Kuttanad, Vellayani and Sasthamkotta.

Absence of beta and delta residues in water at Vellayani could be due to the settlements of the residues in sediments as shown by a higher proportion of these isomers in sediments at vellayani than in other ecosystems.

Several fold increase of the residue content in sediment compared to those of water revealed that the `sediments' became a `sink' for the pollutants in the ecosystem.

Eteroplus suratensis, *Heteropneustes fossilis* and *Macrobrachium rosenbergii* (at Kuttanad) and *M. idella idella* (Vellayani and Sasthamkotta) contain residues of all isomers of HCH.

In fresh water ecosystem *E. suratensis* had highest residue and it was followed by prawn and *H. fossilis*. In Kuttanad ecosystem *H. fossilis* was most contaminated and it was followed by *M. rosenbergii*. At Vellayani the fishes did not contain beta and delta isomers while the prawns contained all the four isomers. This indicated that the former absorbed the pollutant from water and the latter from water and sediments.

Significant correlations were lacking between the residue content in fishes and the other components subjected to study in the environment.

Residue levels in the animals chosen did not appear to reach hazardous levels. Predominance of beta isomer, known as a chronic toxicant and carcinogen, in the total residue content is alarming.

The backwater and freshwater ecosystems in the state were seen polluted with isomers of HCH. Sustained and extensive monitoring of the residues and effective steps for reducing / eliminating the hazard are indicated.