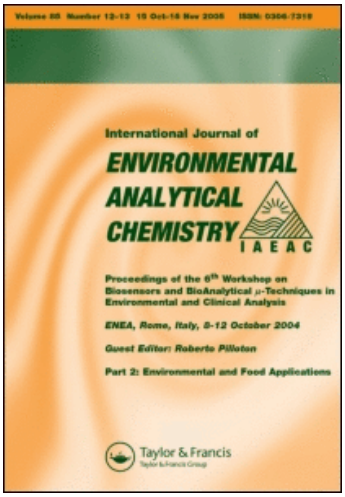

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FATE OF HCH (BHC) IN TROPICAL PADDY FIELD: APPLICATION TEST IN SOUTH INDIA

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A HCH (BHC) application test was conducted in an experimental paddy field in the Vellar river watershed, Tamil Nadu state, South India. Interestingly, most of the HCH applied to the field was found to volatilize rapidly as low residue levels in water, rice plant and soil were recorded. After two weeks of an application, more than 90% of the HCH was found in the air and less than 10% in water, soil and rice plants, thus emphasizing that post-application volatilization is a major route for transport of insecticides to and through the atmosphere in tropical paddy areas.

KEY WORDS: HCH (BHC), tropical areas, rice field, atmospheric transport, volatilization.

INTRODUCTION

The continuing usage of persistent organochlorine insecticides in developing countries from the tropical belt has become a matter of concern with regard to the environmental quality and human health.[1,2] Additionally, some investigations have pointed the significant contribution of the tropical environments to global contamination by these insecticides.[3–5] Though the distribution and behavior of organochlorine insecticide residues in environmental and biological samples from tropical countries like India have been well documented,[6–12] very little attention has been focussed on the environmental fate of these insecticides. Even the studies available were conducted in dry areas[13–16] and in fields without crop cover.[17–19] On the other hand, investigations in wet agricultural lands were few.[20–21] In order to elucidate the environmental fate of organochlorine insecticide residues in tropical environments, an application test of HCH (hexachlorocyclohexane: BHC) was undertaken in a paddy area of the Vellar river watershed, South India.

In view of the intensive consumption of HCH in India, it was used as a representative insecticide in the present study to evaluate the fate of contaminants in the tropics.

STUDY AREA AND METHODS

The experimental paddy field is situated at Parangipettai (11°29'N, 79°46'E) in Tamil Nadu State, South India. This place is located 250 km south of Madras city and a predominantly agricultural area in the watershed of Vellar river. Samples were collected in this field from August, 1988 to January, 1989. The area of the field measured 10 m × 10 m.

Before starting the experiment, the field was uniformly leveled. Rice seedlings (variety IR-20) of 36 days old were transplanted. The plot was irrigated by waters drawn from an irrigation canal and also an artesian well. During the course of the experiment, atmospheric temperatures ranged from 23 to 32°C, cumulative monthly rainfall from 15 to 540 mm, windspeed from 0 to 8 km/hr and relative humidity from 60 to 95%.

200 g (20 g active ingredient) of 10% dust of HCH (technical grade)/100 m^2 were applied to the field. This treatment dosage was similar to that usually applied by farmers in this area during an entire crop season. Air, water, soil and rice plant samples were collected before and after the application of HCH to rice crop.

Air sampling was performed in the field by fixing the air pump and other accessories on the top of a table, 50 cm above the soil surface. Approximately 7 m^3 of air was drawn for 6 hrs into three pieces of prewashed and dried polyurethane foam (18 mmϕ × 50 mm length each) packed in a glass tube, at a flow rate of 24 l/min using an air pump (Model RK-1400, Kofloc No. 2, Kojima Co. Ltd., Japan). Power supply to the air pump was provided by a portable generator (Model Shriram Honda EM 650, 220 V Ac; Shriram Power Equipment Ltd., India).

About 18 to 20 l of paddy field water was passed through prewashed and dried Amberlite XAD-2 resin packed in a glass tube. Air (polyurethane foam tubes) and water (XAD resin tubes) samples were frozen at −20°C until analysis.

Soil samples were collected from 5 points in the experimental plot. The upper 5 cm of soil were dug and placed in polyethylene bags. In the laboratory, these composite samples were air-dried and mixed thoroughly. All the samples collected were shipped to Japan for analyses.

Air, water and soil samples were analysed following the methods of Ramesh *et al.*,[9,10,22] Rice plants were cut to 3–5 mm size, ground and mixed well. Approximately 5 g of sample was taken in a 250 ml conical flask and 100 ml of acetone were added and shaken for 2 hrs. The supernatant liquid was transferred into a separatory funnel containing 120 ml of hexane and 600 ml of hexane washed water. The rest of the procedure was similar to that followed for paddy soil samples. Quantification of HCH isomers in all the samples collected followed the methods reported earlier.[9–11]

RESULTS AND DISCUSSION

A progressive decrease in residue levels corresponding with an increase in time has been observed in air, water and soil in the paddy field after HCH application (Figure 1). Among the three compartments, HCH concentration (sum of α, β, γ and δ isomers)

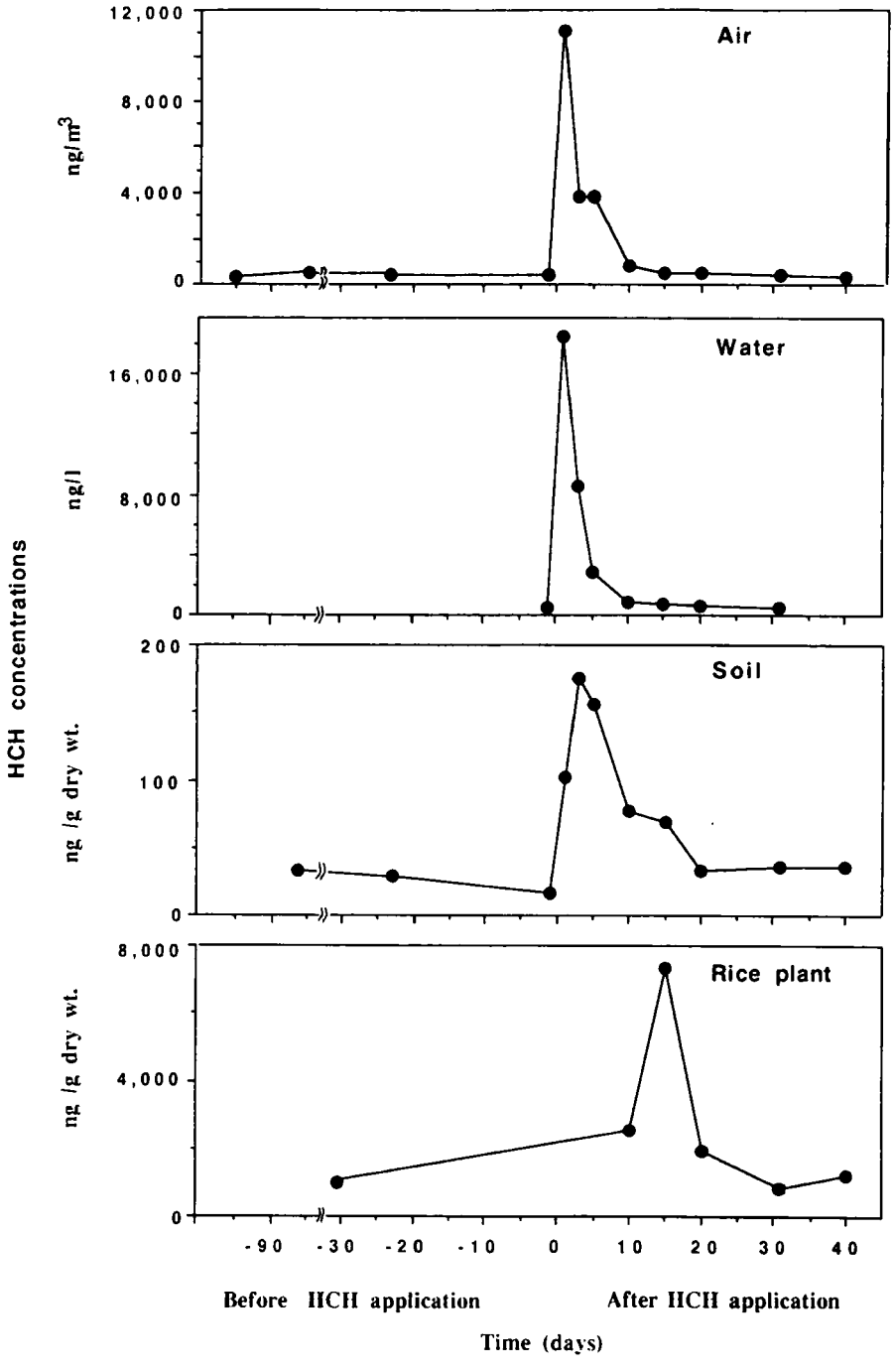

Figure 1 Time course of HCH concentrations in the different compartments of the experimental paddy field.

fell down to nearly or less than half of their initial levels within 10 days of insecticide application. By the end of 40 days, the HCH levels in air, water and soil were comparable to their concentrations recorded before the insecticide application. This could be due to the rapid evaporation of HCH from paddy field water and soil after insecticide application and transport of the volatilized HCH through air. The rapid release of HCH from the paddy field into atmosphere as observed in the present study support our earlier findings[9] that the contribution of HCH to atmospheric phase is high during the flowering season of rice crop.

Our results on the fast disappearance of HCH from paddy field in South India were in agreement with other field trials conducted on HCH persistence in soil from different parts of India. Chawla *et al.*[23] reported that after HCH application in Ludhiana, Punjab, its levels in soil decreased by 95% in 112 days. Kathpal *et al.*[24] noticed that HCH levels in soil of Hisar, Haryana fell to 99% of its original concentration after 100 days of the insecticide application. Samuel *et al.*[18] found that 50% of the HCH applied to soil in Delhi was lost in 30–45 days. Kaushik[25] estimated that 94% of HCH was lost 60 days after its application to soil in Delhi. Interestingly, in the present study HCH levels in soil reduced by more than 70% after 39 days of application, probably due to the effect of higher temperatures than the above mentioned areas.

The time course loss of HCH residues in experimental field is also reflected in the percentage composition of its isomers in the various compartments of the paddy field. These data shown in Figure 2 is summarized as follows.

Air	$\alpha > \gamma > \beta > \delta$	
Water	$\alpha > \beta > \gamma > \delta$	
Soil	$\alpha > \beta > \gamma > \delta$	(earlier days of application)
	$\beta > \alpha > \delta > \gamma$	(later days of application)
Paddy plant	$\beta > \alpha = \delta > \gamma$	

High percentage of α isomer was recorded in all the above environmental compartments, reflecting the composition of technical HCH sprayed (α 70%, γ 14%, β 9% and δ 7%)[9]. Generally, HCH behavior is controlled by the physico-chemical properties of the individual isomers. In the case of air samples, γ ranked next to α. These two isomers have higher vapor pressures (α: 3.1×10^{-5} mmHg; γ: 6.4×10^{-5} mmHg at 25°C) than the rest of the HCH isomers (β: 0.7×10^{-6} mmHg; δ: 2.4×10^{-5} mmHg at 25°C).[26] The atmospheric temperatures might have facilitated their rapid volatilization. Although the contribution of β-HCH in technical HCH is smaller (ca. 9%) than γ (ca. 14%) and slightly higher than δ-HCH (ca. 7%), its concentration was apparently high in paddy field water and soil (close to α). It is known that β-HCH has the lowest water solubility and vapor pressure, but it is the most stable among HCH isomers[27] and also resistant to microbial degradation.[28] Considering these physico-chemical and biochemical properties it could be assumed that γ-HCH rapidly escape from agricultural areas through air and hence somewhat higher levels continue to be there for a short while after insecticide application. On the contrary, β-HCH

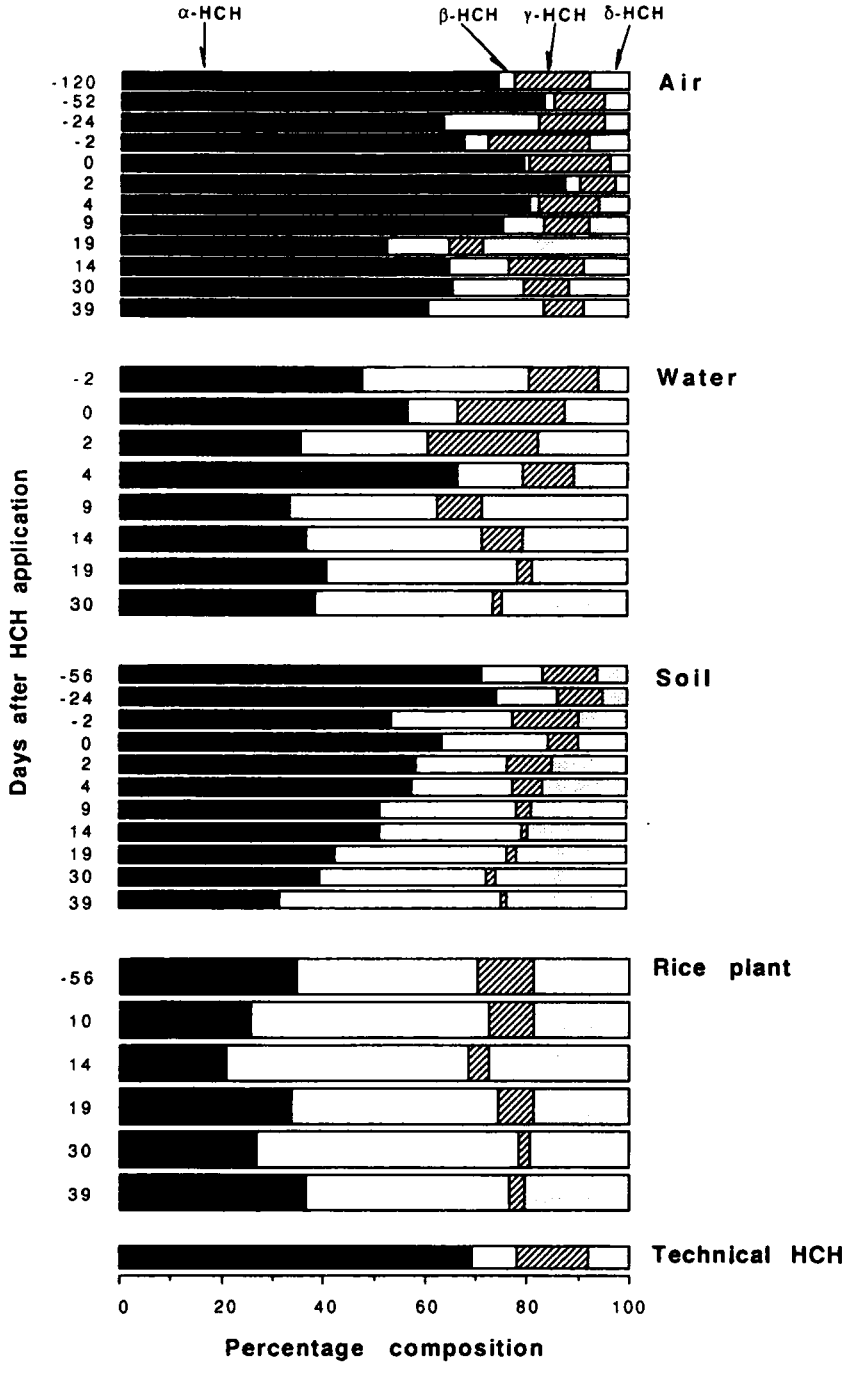

Figure 2 Percentage composition of HCH isomers in the experimental paddy field.

is the persistent one in soil and crops and hence the contribution of this isomer to paddy field water is expected to continue for a considerable period after application. In the case of rice plant, the percentage of β isomer was relatively higher than that of α isomer. Fast disappearance of α and γ isomers from the rice plants to the atmosphere may be a possible reason.

Based on the concentrations of HCH in air, water, soil and rice plant in the experimental paddy field, the residual amounts (%) of insecticide existing in each of the above phases was calculated using the following approximations. On the basis of these data, the environmental fate of HCH applied in the paddy field was quantitatively determined.

(i) Soil

Depth of the soil layer, and water content of the soil were assumed as 5 cm and 50%, respectively. Since the area of the experimental plot was 100 m^2, the total weight of the soil becomes 2.5×10^6 g. The residual amount of HCH in soil was calculated by multiplying the HCH concentrations in soil with that of the soil weight.

(ii) Rice plant

The weight of a full grown rice plant in a stalk could be 700 g. About 1,100 of them were planted in an area of 10 m width of paddy. Hence the total weight of the rice plants will be about 770 kg. As the water content in the plants differ from day to day, the total weight of the rice plants were adjusted (taking the water content into consideration) to obtain the actual weight. By multiplying the HCH concentrations in rice plants at each sampling day with that of the actual weight, the residual amounts of HCH in the rice plants were calculated.

(iii) Water

Depth of the water layer in the paddy field was assumed to be 10 cm. As the area of paddy field is 100 m^2, the total volume of water in the plot is 10^4 l. By multiplying the HCH concentrations in water with the total volume of water in the paddy field, the residual amount of HCH in water was calculated. In this area, usually during cropping season, water ponded in rice fields is always supplemented after evaporation. Hence in these calculations, the escape of HCH through water was regarded as negligible because outflow of HCH is mainly through evaporation, but not runoff and percolation.

(iv) Air

As air is continuously exchanged in the paddy field, the integrated HCH amounts from the beginning of sampling until the last sampling date were calculated for air. These values correspond to the amount dispersed through air. The amount of HCH

dispersed through the air and half-lives of individual HCH isomers were calculated by the following equation.

$$D = 10^{-9} V \int_0^T C\, dt$$

D = total amount of HCH dispersed through air (g)

$C = C_0 e^{-kt}$

C = concentration in the air (ng/m^3)

k = rate constant

t = time (in days)

C_0 = concentration at time 0

T = time from the date of HCH application (days)

V = volume of air (0.72×10^6 l) transferred over the paddy field per day (assuming that the effective height of air in paddy field is equal to that of the height of paddy plant [approximately 1 m] and a wind speed of 3 km/hr).

The half-life of HCHs in the air was estimated as 5 days (Table 1). Data on half-lives of individual HCH isomers were in line with those of their vapor pressures. These results show that volatilization is the prominent pathway for HCH escaped from the paddy fields than other ways such as photodegradation, microbial degradation or outflow through water.

Table 2 shows the residual amount of HCHs in each compartment of the experimental paddy field. Generally, higher values were recorded in atmosphere than water and paddy soil. However, in the initial days of application, the estimated HCHs were high in the "unknown" category. The interaction among environmental parameters and/or some other factors not covered in the above equation for air might have contributed to initial high values of HCH in the unknown category. Consequently, the environmental load of HCH in the earlier days of HCH application can not be considered as representative of the actual situation in the field. Notwithstanding this variation, the above calculations showed that most of the HCH applied

Table 1 Initial concentrations, rate constants, correlation coefficients and half-lives for the disappearance of HCHs in air.

HCH isomers	C_0(*ng/g*)	*K*	r^2	*Half-life* (*day*$^{-1}$)
α-HCH	3400	0.15	0.89	5
β-HCH	93	0.075	0.96	9
γ-HCH	450	0.15	0.84	5
δ-HCH	190	0.11	0.92	6
THCH	4300	0.14	0.90	5

Table 2 Residual amounts (gms) of HCHs in the experimental paddy field.

Days after application	*Air**	*Water*	*Soil*	*Paddy plant*	*Unknown*
2	5.5	0.81	0.45	7.7	5.5
4	9.5	0.24	0.38	0.38	9.5
9	16	0.036	0.18	0.40	3.8
14	19	0.029	0.16	2.1	−1.3
19	20	0.016	0.068	0.56	−0.64
30	21	0.05	0.078	0.32	−1.5
39	22	—	0.073	0.63	−2.7

* Cumulative values.

to the paddy field was released to the air. Out of 20 g of the HCH applied, more than 90% was found in air, less than 10% in water, soil, and paddy plants two weeks after application. The percentage of residual amount of HCH in each compartment is shown in Figure 3. On the whole, our results highlight the considerable emissions of HCH through air from tropical paddy areas.

The present findings support results from our previous studies on HCH flux in the coastal environment[4] where we found that about 99.6% of the applied HCH in the paddy areas of this watershed was removed to the air and only 0.1% drained to the sea. These results reiterate that transfer of applied pesticides to the atmosphere is quite large in tropical areas.

The low residue levels of HCH in sediments[22], mussels[11] and also quick volatilization of it from the paddy areas (present study) also emphasize the rapid dissipation of HCH through air, despite the extensive usage of this insecticide in India. The short

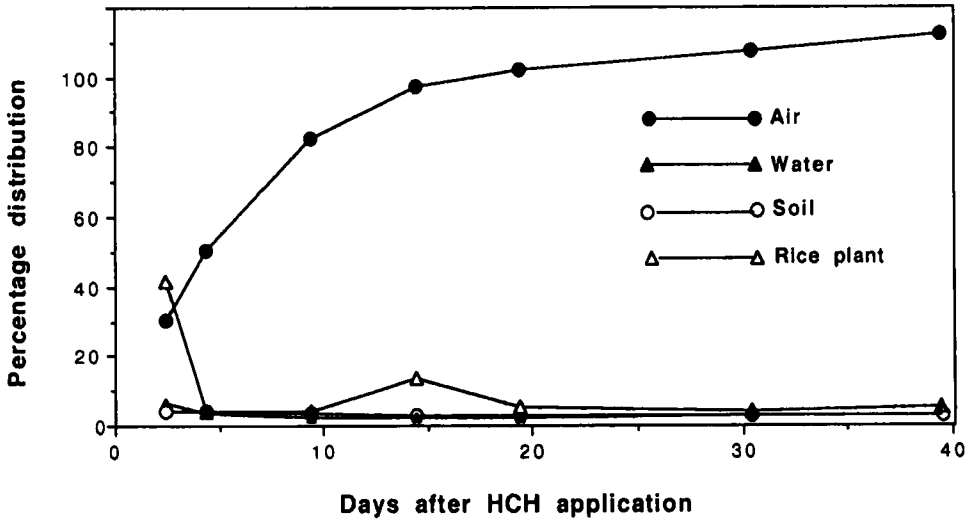

Figure 3 Residual amount (%) of HCH in various compartments of the experimental paddy field.

residence time of it in wet agricultural fields and nearby areas enabled us to comprehensively assess the fact of HCH in tropical point-source areas.

The information obtained in the present study on the behavior and fate of HCH in an experimental paddy field could also be extrapolated to other agricultural areas in the tropical belt where large quantities of the applied insecticides like HCH are volatilized. This will have an impact on the environment in global terms as these volatilized residues contribute to the atmospheric organochlorine budget, carried away through long-range transport to places far away from the point-source.

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