

DEGRADATION OF 14C-DDT IN A SANDY LOAM AS AFFECTED BY TEMPERATURE IN THE LABORATORY

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Abstract

One hundred gram (100g) portions of a moist sandy loam (Oxic Haplustalf), obtained from the plough layer of a plot with no known history of pesticide application at the University of Ilorin, Ilorin, Nigeria were amended with 8 μ Ci of 14C-DDT (Dichloro-diphenyltrichloro-ethane) and 10mg cold DDT in 10ml n-hexane. Triplicate samples in static microcosm were incubated for 42 days at ambient (25 $^{\circ}$ \pm 2 $^{\circ}$ C), 35 $^{\circ}$ C and 45 $^{\circ}$ C respectively. The experimental design was completely randomised block. The experiment was extended to 91 days at ambient temperature. Evolved 14CO₂ and organic volatiles were absorbed in 1N NaOH and n-hexane respectively. The 14C activity was determined weekly using a Beckman liquid scintillation beta counter. Temperature quotients (Q₁₀) were calculated for the loss of carbon as CO₂ and organic volatiles.

The results show that the microbial degradation of 14C-DDT in soil takes place within mesophilic temperatures with optimum at about 35 $^{\circ}$ C. Total loss of 14C-DDT as organic volatiles was not significantly increased at temperatures greater than 35 $^{\circ}$ C. Over time, microbial degradation would be more important than volatilization in the process of loss of 14C-DDT from the soil system.

INTRODUCTION

One of the factors militating against food self-sufficiency in the tropics is pest infestation. This is why pesticide applications have been incorporated into the more land intensive agricultural systems being practiced today. However, long-term soil fertility and

biochemical processes have been reported to be adversely affected by pesticide applications (Alexander, 1977; Tu, 1978; Perfect, 1980; Roslycky, 1986; Somda *et al.*, 1991). Dichloro-diphenyl-trichloro-ethane (DDT) is a cheap, effective and broad-spectrum organochlorine compound. It is one of the most apolar compounds known to exist, hence its low water solubility (< 2ppb) and persistence (Nash and Woolson, 1967; Matsumura, 1975; Bayer and Gish, 1980). Because of its persistence, this pesticide has either been restricted or totally banned since the 1970's in the developed industrial nations. Based on the drawbacks found under temperate conditions, environmentalists have also been campaigning for a ban of DDT use in the tropics. However, some postulate that DDT may not be persistent under tropical conditions because of the high rainfall and temperature regimes. As temperature is one of the most important factors affecting chemical and biological reactions in soil (Skipper *et al.*, 1967; Kaufman and Kearney, 1970; Alexander, 1977) this study was undertaken in order to assess the effect of temperature on the loss of ¹⁴C-DDT carbon in a sandy loam in the laboratory.

MATERIALS AND METHODS

Incubation Study:

Field moist sample of a sandy loam (Oxic Haplustalf) was obtained from the plough-layer (0 - 15cm) of a plot with no known history of pesticide application at the University of Ilorin, Ilorin, Nigeria. The sample was kept in humidified chamber for 2 days in order to stabilise microbial activity. A sub-sample, air-dried and passed through 2mm sieve was subjected to physical and chemical analysis. Particle size analysis by the hydrometer method (Bouyoucos, 1962) showed that the soil contained 73% sand, 12% silt and 15% clay; pH (0.01M CaCl₂), 5.2; organic C, 1.09%, NO₃-N, 12.1mgkg⁻¹; Bray-1P, 6.3mgkg⁻¹; exchangeable Ca, K, Mg, Na and CEC, 5.63, 0.51, 0.57, 0.52 and 7.23 cmolkg⁻¹ respectively. The study was conducted according to the International Atomic Energy Agency protocol (IAEA) (1983). One hundred gram (100g) portion of soil (oven-dry basis) weighed into 500ml Erlenmeyer flask was amended with 8μCi of ¹⁴C-DDT and 10mg cold DDT in 10ml n-hexane. Triplicate samples, in tightly corked flasks, were incubated for 42 days at ambient, mesophilic and thermophilic temperatures, viz, 25 ± 2°C, 35°C and 45°C respectively. The experimental design was completely randomized block. The incubation experiment, carried out in static microcosm, was extended to 91 days at ambient temperature. Evolved ¹⁴CO₂ and organic volatiles were absorbed in 1N NaOH and n-hexane respectively. A Beckman Liquid Scintillation beta counter (LSC) was used to determine the ¹⁴C activity in evolved ¹⁴CO₂ and radiochemical organic volatiles.

RESULTS AND DISCUSSION

Effect of temperature on ¹⁴C lost as CO₂ and organic volatiles:

Table 1 (a,b,c) shows the percent of carbon applied as ¹⁴C-DDT lost with time from a sandy loam soil at different incubation temperatures in the laboratory. At the end of the 7th and 14th days, CO₂ evolution at 35 and 45°C were significantly higher (P = 0.05) than at

the lower ambient temperature. (Table 1a). However, thereafter while the CO₂ evolved

Table 1: Evolution of ¹⁴C as CO₂ (a) organic volatiles (b) and the total loss (c) expressed as percent of ¹⁴C-DDT carbon applied to a sandy loam at different temperatures in the laboratory.

(a)

Treatment	Length of Incubation (Days)						Mean
	7	14	21	28	35	42	Total
Ambient	1.4	1.4	3.2	4.8	3.6	3.1	17.50
35°C	2.4	3.6	3.7	4.1	4.9	5.6	24.30
45°C	4.2	4.5	0.8	0.8	0.6	0.4	11.30
Mean	2.67	3.17	2.57	3.23	3.03	3.03	17.70
SE+	0.10	0.12	0.15	0.11	0.06	0.07	0.20
LSD 0.05	0.35	0.43	0.50	0.38	0.20	0.26	0.68

(b)

Ambient	4.6	2.2	1.8	1.7	1.6	0.7	12.60
350C	6.5	4.5	4.3	3.1	3.0	3.0	24.40
450C	0.3	2.6	4.3	5.3	5.4	5.4	23.30
Mean	3.80	3.10	3.47	3.37	3.33	3.03	20.10
SE+	0.07	0.07	0.11	0.07	0.07	0.03	0.21
LSD 0.05	0.26	0.26	0.37	0.26	0.23	0.11	0.74

(c)

Ambient	6.0	3.6	5.0	6.5	5.2	3.8	30.10
35°C	8.9	8.1	8.0	7.2	7.9	8.6	48.70
45°C	4.5	7.1	5.1	6.1	6.0	5.8	34.60
Mean	6.47	6.27	6.03	6.60	6.37	6.07	37.80
SE+	0.11	0.14	0.17	0.16	0.08	0.07	0.24
LSD 0.05	0.38	0.48	0.59	0.54	0.28	0.26	0.83

at ambient temperatures was significantly lower ($P = 0.05$) than at 35°C, it was significantly higher ($P = 0.05$) than at 45°C. This trend along with the fact that the Q_{10} values for CO₂ evolution (Table 2) between ambient and 35°C and between 35°C and 45°C were 1.39 and 0.47 respectively, indicates that the optimum temperature for the microbial mineralization of the ¹⁴C-DDT was at about 35°C. For atrazine, Roeth et al. (1969) found a 2-3 fold increase in degradation when incubation temperature was increased from 15 to 35°C. Clayinka and Adebayo (1984) found similar Q_{10} values in sawdust-amended soil and also

concluded that the optimum temperature for soil organic carbon mineralization was between 30 and 35°C. Further, soil microorganisms especially bacteria and fungi have been found to play significant roles in the transformation of pesticides in the soil (Levanon, 1993). Since the microorganisms in agricultural soils are mesophiles, the trend obtained at 45°C indicated a lack of thermophilic species in this soil.

At the end of the 7th and 14th days of incubation, the percent of applied 14C-DDT that volatilized was highest at 35°C. (Table 1b). The reason for this is not very clear. However, after the 21st day and up to the end of incubation, significantly higher ($P = 0.05$) amounts were volatilized at 45°C than at the lower temperatures. This trend confirms the fact that volatilization is mainly a physical process. However, there was greater increase in the

Table 2: Temperature quotients (Q_{10}) for 14C mineralization (a) organic volatiles (b) and the total loss (c) from 14C-DDT in a sandy loam at different temperatures in the laboratory.

Q_{10} values	Length of Incubation (Days)						Mean Total
	7	14	21	28	35	42	
(a)							
Ambient-35°C	1.71	2.57	1.16	0.85	1.36	1.81	1.30
35°C - 45°C	1.75	1.25	0.22	0.20	0.12	0.07	0.47
(b)							
Ambient-35°C	1.41	2.05	2.39	1.82	1.88	4.29	1.94
35°C-45°C	0.05	0.58	1.00	1.71	1.80	1.80	0.95
(c)							
Ambient-35°C	1.48	2.25	1.60	1.11	1.52	2.26	1.62
35°C - 45°C	0.51	0.88	0.64	0.85	0.76	0.67	0.71

overall volatilization (Table 1b) and total C loss (CO_2 + organic volatiles) (Table 1c) between ambient temperature and 35°C than between 35 and 45°C considering the Q_{10} values of 1.94 and 1.62; and 0.95 and 0.71 respectively. (Table 2). Throughout the 42-day incubation period, the % of applied C lost as CO_2 and organic volatiles (total loss) (Table 1c) at 35°C was the highest. This trend is attributable to the enhancement of CO_2 evolution at 35°C more than at 45°C (Table 1a). However, because the incubation took place in closed microcosm, the trend in the field might be different.

The loss of C as CO_2 and organic volatiles at ambient temperature between the 49th and 91st days of incubation is presented in Table 3. The losses were more or less constant throughout the period. However, higher amounts were lost as CO_2 compared with the organic volatiles. Hence, with time microbial degradation of residual 14C-DDT would be a more important process of loss from the soil system.

CONCLUSION

These results show that the microbial degradation of 14C-DDT in soil takes place within mesophilic temperatures with optimum at about 35°C. Total loss of 14C-DDT as organic volatiles was not also significantly increased at temperatures greater than 35°C. In the long run, microbial degradation would be more important than volatilization in the process of loss of 14C-DDT from the soil system.

Table 3: Loss of 14C as CO₂, organic volatiles and the total loss expressed as percent of 14C-DDT carbon applied to a sandy loam at different temperatures in the laboratory.

Treatments	Length of Incubation (Days)							Mean Total
	49	56	63	70	77	84	91	
14CO ₂	3.6	2.4	3.0	3.2	3.2	2.8	3.6	21.80
Organic Volatiles	0.3	0.3	0.3	0.3	0.1	0.1	0.1	1.50
14CO ₂ + organic volatiles	3.9	2.7	3.3	3.5	3.3	2.9	3.7	23.30

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