

5.4 Fate and Effects of Aldrin/ Dieldrin in Terrestrial Ecosystems in Hot Climates

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5.4.1 INTRODUCTION

Aldrin and its epoxide dieldrin are largely used in countries with hot climates, both as agricultural insecticides and for the control of tsetse fly, the vector of human and animal trypanosomiasis, and other insects which are sources of various human and animal diseases. Whereas in industrial countries the use of aldrin and dieldrin has been restricted or banned within the last decade, their use continues in developing countries with hot climates.

It is self evident that the fate and residue behaviour of both these insecticides in terrestrial ecosystems of hot climates are different from their fate in temperate climates. The fate in temperate climates has been investigated in numerous studies reported in literature (e.g. Elgar, 1966; Kohli *et al.*, 1973; Klein *et al.*, 1973; Stewart and Gaul, 1977). As a consequence of the differences in persistence, differences are also evident in the effects on ecosystems. However, only limited information is available on these differences. This study attempts to review experiments carried out in terrestrial ecosystems under tropical, subtropical, and Mediterranean conditions and to evaluate them with regard to data in temperate climates.

5.4.2 RESIDUE BEHAVIOUR OF ALDRIN/DIELDRIN IN SOILS IN HOT CLIMATES

In general, two climatic factors affect the residue behaviour and persistence of chemicals in terrestrial ecosystems: temperature and humidity; composition of soil to a considerable extent is also directly related to climate. The influence of these climatic factors on each of the mechanisms and pathways involved in residue decline in soil affects the persistence of chemicals in soil. The major mechanisms and pathways involved in residue decline in soil are volatilization, mobility and leaching, and degradation, including primary degradation (mainly conversion), as well as total degradation to carbon dioxide

(mineralization). In the following paragraphs, studies on each of these pathways related to aldrin/dieldrin in hot climates will be discussed.

5.4.2.1 Volatilization

Field studies reporting direct measurements of dieldrin in the air above treated areas in temperate climates have shown that volatilization is an important pathway of residue loss (Caro and Taylor, 1971; Willis *et al.*, 1972; Taylor *et al.*, 1976; Turner *et al.*, 1977). Climatic factors have a considerable influence on this pathway. Since higher temperature results in higher vapour pressure of aldrin and dieldrin, volatilization of pure as well as of adsorbed substances increases with increasing temperature. Kushwaha *et al.* (1976) reported a rapid loss of aldrin from a glass plate at higher temperatures. Similarly, temperature affects volatilization of aldrin and dieldrin from moist soils.

Today, it is assumed that volatilization from moist soils occurs mainly in the liquid phase (Hamaker, 1972). Therefore, a decrease in adsorption due to climatic or soil factors will result in an increase in residue loss from soil. Since adsorption is negatively correlated to water solubility (Kenaga and Goring, 1978; Chiou *et al.*, 1979; Felsot and Dahm, 1979; Briggs, 1981) which, in turn, is positively related to temperature, an increase in temperature will result in an increase in the portion of chemical desorbed in soil solution. The volatilization of chemicals from aqueous solutions, too, depends strongly on temperature, as regards both the temperature dependence of vapour pressure and of liquid-phase transfer velocities (Mackay and Yuen, 1983; Downing and Truesdale, 1955; Wolff and van der Heijde, 1982). For gas-phase controlled substances, such as aldrin and dieldrin, temperature-related increase in vapour pressure results in a considerable increase in volatilization.

Harris and Lichtenstein (1961) found that increased temperature increased the volatilization of aldrin from soil; for a Plainfield sand, an increase in temperature of about 10°C increased the rate of volatilization more than twofold. Farmer *et al.* (1972) demonstrated, for Gila silt loam, that an increase in temperature of 10°C increased the rate of volatilization of dieldrin approximately fourfold.

Higher moisture content of soils also influences volatilization positively (Spencer *et al.*, 1973). This increase in volatilization is not due to 'co-distillation' phenomena but to a displacement of the insecticides by water from the adsorption sites (Igue *et al.*, 1972).

From all these observations reported, it may be assumed that the increase in residue dissipation observed in hot and moist climates, as discussed in paragraph 5.4.2.4, is due more to enhanced volatilization than to enhanced degradation.

5.4.2.2 Mobility and Leaching

As for volatilization from soil, adsorption of chemicals in soil is also a key

parameter for their mobility and leaching. Adsorption coefficients of chemicals in soil vary largely depending on soil type, and especially on the organic carbon content of the soil (Lambert *et al.*, 1965; Spencer *et al.*, 1973; Felsot and Dahm, 1979; Rippen *et al.*, 1982). Therefore, adsorption of aldrin/dieldrin in tropical soils will be greater or smaller than in soils of temperate climates, depending on the organic carbon content. In moist tropical and subtropical regions, weathering and mineralization are very intensive due to high temperatures and high moisture contents. For the same reason, bioactivity in soil and hence degradation of dead plant material are more intensive, often resulting—in spite of higher plant growth and plant decay—in a lower humus content than in central European soils. However, there exist also tropical soils with high organic carbon contents (Scheffer and Schachtschabel, 1982).

Baluja *et al.* (1975) demonstrated, for three soils from Spain with an organic matter content between 1.7 and 7.9%, a high adsorption rate of aldrin and a nearly zero desorption rate. Thin-layer chromatography on seven Brazilian soils, with organic matter contents of between 0.6 and 13.1%, demonstrated that aldrin was strongly adsorbed and did not move from the point of application for any soil (Lord *et al.*, 1978).

Temperature may also influence the adsorption which is usually exothermic. Higher temperature probably decreases adsorption and releases insecticides. Solubility of insecticides is also temperature dependent, thus leading to a decrease in adsorption when the temperature rises and more of the adsorbed insecticide becomes dissolved in soil water (Edwards, 1966).

Under environmental conditions, rainfall is another important factor affecting mobility of chemicals in soil. Therefore, mobility of aldrin/dieldrin in soil is greater in moist climates than in dry ones. A comparative outdoor lysimeter study in a moderately moist climate (Germany) and a warm dry climate (Spain) showed that, within one vegetation period, 21% of the aldrin recovered after application to a depth of 10 cm had moved to deeper layers in the moist climate, whereas only 3.5% had done so in the Mediterranean climate. These differences were mostly due to marked differences in rainfall. This conclusion was confirmed by further experiments in other countries (Weisgerber *et al.*, 1974).

However, at least for unchanged aldrin mobility in soil is of minor importance for residue decline in soil. Conversion to dieldrin and other, more polar compounds, followed by leaching of these, is a more important pathway of residue loss from soils. This probably applies to both temperate and hot climates.

5.4.2.3 Degradation (Conversion and Mineralization)

Primary degradation of a chemical is the disappearance of the parent compound by chemical reactions of every kind, including small alterations in the molecule as well as total mineralization to carbon dioxide. For aldrin in the soil-plant

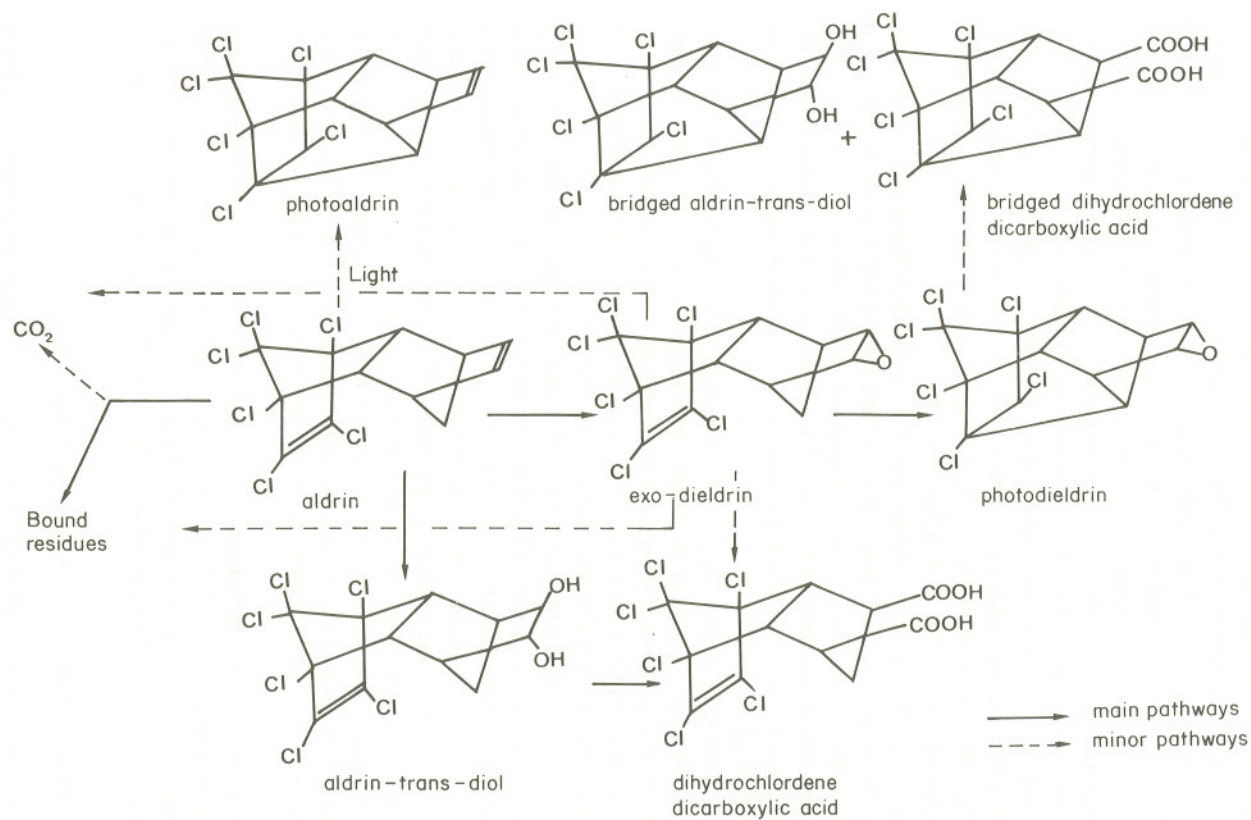


Figure 5.4.1 Conversion pathways of aldrin in plants and soil under outdoor conditions (Scheunert *et al.*, 1977). Reproduced with permission of Academic Press

system, primary degradation comprises all pathways shown in Figure 5.4.1 (Scheunert *et al.*, 1977).

Studies in a temperate climate with ^{14}C -aldrin have shown that the only soluble conversion products of aldrin which were quantitatively significant ($>1\%$ of total ^{14}C -residues) were dieldrin, photodieldrin, and the ring cleavage product, dihydrochlordene dicarboxylic acid. For dieldrin, the only significant soluble conversion product was photodieldrin—a compound which does not represent to any relevant degree a step towards smaller molecules since it was shown to be metabolized only by less than 2% within one year (Weisgerber *et al.*, 1975). Residues bound in soil were formed both from aldrin and dieldrin—from aldrin about 11% , from dieldrin about 1% of total recovered residues within one growing period (Sotiriou *et al.*, 1981). For aldrin, about half of the soil-bound residues could be released by dilute alkali solution and were found to be dihydrochlordene dicarboxylic acid. The chemical nature of the remaining portion of bound residues is not known.

Since microbial processes are normally accelerated by higher temperatures, it is assumed that conversion reactions are higher at higher temperatures. In a comparative outdoor lysimeter study with ^{14}C -aldrin for one vegetation period, unchanged aldrin constituted about 50% of the total ^{14}C residue in soil (0–10 cm depth) in a cool temperature climate, whereas it was 38% in a warm Mediterranean climate. This corresponds to 59 or 58% aldrin, respectively, based on the sum of aldrin and dieldrin, irrespective of other metabolites. A corresponding figure from India for the same time period was 50% (Agnihotri *et al.*, 1977). In another Indian study, aldrin represented more than 90% of the sum of aldrin and dieldrin after 91 days under beet cover (Gupta and Kavadia, 1979). According to these authors, soil moisture content is responsible for differences in aldrin epoxidation.

Other authors (Lichtenstein and Schulz, 1959a; Kushwaha *et al.*, 1978) found a positive temperature-dependence for the conversion of aldrin to dieldrin—i.e. increase with increasing temperature. The conversion of aldrin to polar soluble and soil-bound products—i.e. conversion steps initiating a real degradation—was higher in a warm climate (Weisgerber *et al.*, 1974).

The ability of fungi isolated from Brazilian soils to adsorb and metabolize ^{14}C -aldrin and its metabolites was assayed in a culture growth medium after 76 days of incubation (Musumeci *et al.*, 1982). All the 14 isolates incorporated the radiocarbon as demonstrated by wet combustion of the mycelium. Four of the fungi were able to further metabolize one of the compounds added to the medium.

Total mineralization (utilization) of dieldrin by fungi from Sudanese soils, without detectable intermediate products, was concluded by El Beit *et al.* (1981) from a substantial difference in dieldrin recovery between inoculated samples and controls. However, the utilization of dieldrin as a carbon source could not be demonstrated in carbon-free mineral-salt media since fungi did not grow there.

It may be concluded that an acceleration of conversion and mineralization of aldrin/dieldrin by soils in tropical or subtropical regions could take place, but that an unequivocal demonstration of this is still lacking due to an insufficiency in exact comparative studies.

5.4.2.4 Total Residue Losses from Soils

Total residue losses of aldrin/dieldrin from soil, which represent the sum of losses by volatilization, mobility and leaching, conversion, and degradation, were dependent upon temperature, as measured by several authors.

Kiigemagi *et al.* (1958) found a more rapid disappearance in summer than in winter of aldrin and dieldrin residues. Lichtenstein and Schulz (1959b) found that no aldrin was lost in frozen soils, whereas considerable losses were observed at 7°C, 26°C, and 46°C, and the losses increased with increasing temperature (Figure 5.4.2). In contrast to these findings, Kushwaha *et al.* (1978) reported a shorter half-life of aldrin residues at lower temperatures (25°C) than at higher temperature (35–45°C). Probably in this case, soil microorganisms had optimal conditions at 25°C as compared to higher temperatures. Furthermore, in the bags used in the laboratory, volatilization of aldrin was largely suppressed. Under environmental conditions, however, temperatures of 45°C or more are very rare in agricultural soils, and volatilization is efficient. Therefore, in field studies, an increase in residue loss was generally observed for hot climates as compared to temperate climates.

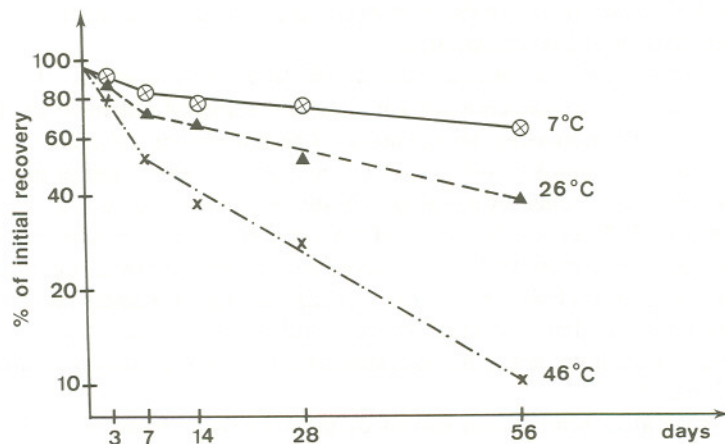


Figure 5.4.2 Loss of aldrin residues from a Plainfield sand as affected by temperature. Application rate: 100 lb/6" acre (Lichtenstein and Schulz, 1959b). Reproduced with permission of the Entomological Society of America

Atabaev *et al.* (1970) conducted field experiments under arid hot climatic conditions in Uzbekistan (South Russia). They found that aldrin disappeared from the upper soil layer (0–30 cm depth) after two years, and from deeper layers (70–100 cm depth) after five years or more.

Agnihotri *et al.* (1976, 1977) reported a high loss of aldrin and its metabolite dieldrin under field conditions in India: 87.9% after 100 days, 98.7% after 180 days. Under different Indian climatic conditions, Kathpal *et al.* (1981) registered an aldrin dissipation of 89–93% within three months and 92–100% within 8.5 months (aldrin only), corresponding to 69–77% after 8.5 months when the sum of aldrin and its metabolite dieldrin was considered. Similarly, Chawla *et al.* (1981) found an aldrin reduction of 89% in soil during the potato-growing period in India. For soil under the cover of sugar beets, the reduction of aldrin and dieldrin was 65% within 91 days (Gupta and Kavadia, 1979). Within 84 or 120 days, about 76–93% of aldrin were lost from soil under field conditions in Udaipur, India (Kushwaha *et al.*, 1981).

Under subtropical conditions in Taiwan, a long-term experiment was undertaken to investigate the persistence of dieldrin following its repeated seasonal application to soil (Talekar *et al.*, 1977). Dieldrin was sprayed or broadcast uniformly and rototilled immediately to a depth of 15 cm; soil samples were taken also to a depth of 15 cm. The decline in the concentration of dieldrin was 25% in the fall and winter; additional treatment during the following spring did not lead to an accumulation of dieldrin residues in soil, and the concentration at the end of summer was virtually identical with that immediately before the treatment. The persistence of dieldrin in this subtropical area thus appeared to be much shorter than under temperate conditions.

In contrast to this study where dieldrin was incorporated into the soil, another study carried out in the Sudan (El Zorgani, 1976) investigated the persistence of aldrin and dieldrin after surface application. In Figure 5.4.3, the disappearance of soil surface residues of aldrin and dieldrin is presented. The figure shows remarkably fast rates of loss of surface deposits of both insecticides. The residues of aldrin are expressed as the sum of aldrin plus its metabolite dieldrin. The faster disappearance rate of aldrin-derived residues as compared to that of dieldrin-derived residues is probably due, on the one hand, to the higher vapour pressure of aldrin and, on the other hand, to additional degradation pathways of aldrin through routes not involving dieldrin formation (see Figure 5.4.1).

Elgar (1975) carried out a comprehensive comparative investigation of the dissipation and accumulation of aldrin-derived residues (aldrin plus dieldrin) in soil at 12 sites in different climatic zones. Aldrin was incorporated immediately after treatment with a rotovator to a maximum depth of 15 cm, and samples were taken also to a depth of 15 cm. Five years of study were reported. The results demonstrated that the difference between the rate of loss at the cool (Northern and Central Europe) and warm (Mediterranean) temperate sites was

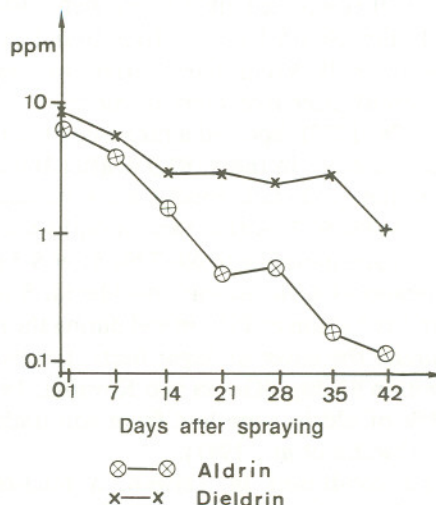


Figure 5.4.3 Disappearance of aldrin and dieldrin residues from soil after surface application in Sudan (El Zorgani, 1976). Reproduced by permission of Springer-Verlag, New York

small, but that the rate of loss at the tropical sites was greater in the first year. There was no correlation between the rate of loss and any of the soil parameters.

The field studies described confirm the conclusions drawn from laboratory experiments reported in paragraphs 5.4.2.1–5.4.2.3, namely that some of the routes of residue disappearance are affected positively by higher temperatures and/or by higher soil moisture contents. It is assumed that the enhanced residue loss under subtropical and tropical conditions is due largely to an increase in volatilization, but degradation is probably also faster in subtropical and tropical soils.

5.4.3 UPTAKE BY PLANTS AND PERSISTENCE ON PLANT SURFACES

Uptake of chemicals by plants is a complex process comprising separate routes, such as root uptake, foliar uptake of vapours in the air or of deposits of sprays or of dust, or uptake through oil cells of lipid-containing plants (Topp *et al.*, 1986; Hulpke and Schuphan, 1970). In view of the assumed negative temperature-dependence of soil adsorption discussed in paragraphs 5.4.2.1 and 5.4.2.2, both root and foliar uptake should be positively influenced by temperature. However, comparative studies for aldrin and dieldrin under both temperate and tropical or subtropical conditions, have not been reported thus far.

In a comparative outdoor lysimeter study, maize root concentration factors, expressed as concentration of aldrin residues in maize roots divided by concentration in soil, were higher in a temperate climate (Central Europe) than in a warm (Mediterranean) climate (Weisgerber *et al.*, 1974). Like the differences in soil mobility discussed in paragraph 5.4.2.2, observed in the same experiment, these differences in plant uptake are probably due to the high differences in rainfall.

Chawla *et al.* (1981) observed a concentration of 0.09–0.135 ppm aldrin and dieldrin in potatoes in India, under field conditions, when 1.875 kg/ha aldrin was applied. The corresponding figures from German and English lysimeter experiments (2.9 kg/ha) were 0.14 or 0.22 ppm (Scheunert *et al.*, unpublished). However, much higher residue levels of these insecticides in potatoes following soil treatments have been reported from other Indian sites.

It may be concluded that the influence of climate on the uptake of aldrin/dieldrin by plants is not yet clarified. It appears that the differences observed are due to differences in soil properties rather than to climate. Further studies with different crops under hot climatic conditions are needed.

The persistence of dieldrin deposits on plant leaves after spray application in hot climates is another important aspect. The situation might be different from that in temperate climates, e.g. due to higher vapour pressures of dieldrin at higher temperatures. Figure 5.4.4 shows the persistence of dieldrin on leaves from the tree canopy (Koeman *et al.*, 1978) after helicopter applications in Nigeria. A rapid decline in the first two weeks after application is followed by a slower decline between day 14 and day 60 and an even slower one thereafter. This three-stage decline is similar to that observed for aldrin in a long-term (13-year) outdoor study in temperate soil (Scheunert, unpublished); however, the rate of decline is much higher on leaves. The formation of photodieldrin from dieldrin on leaves, a mainly photochemical process, should also be more rapid under tropical conditions. Indeed, after only two weeks, up to 20% of the total amount of dieldrin on leaves from tree canopy in Nigeria had changed to photodieldrin. By contrast, the conversion of dieldrin to photodieldrin on cabbage leaves in a temperate climate was only 5% after 4 weeks (Weisgerber *et al.*, 1970).

5.4.4 UPTAKE BY FAUNA AND EFFECTS ON ECOSYSTEMS

A comprehensive field study on the uptake of dieldrin by fauna and of its ecological effects has been carried out in Adamaoua, Cameroon, by Müller *et al.* (1981). Dieldrin was sprayed by a helicopter as an oil formulation with 18% active ingredient at a rate of 5 l/ha on a gallery forest, about 40 m wide and 3 km long. Some data on residue in faunal species, directly after spraying and one year afterwards, are listed in Table 5.4.1. Side-effects observed on the non-target fauna were summarized as follows. With a single treatment, at least

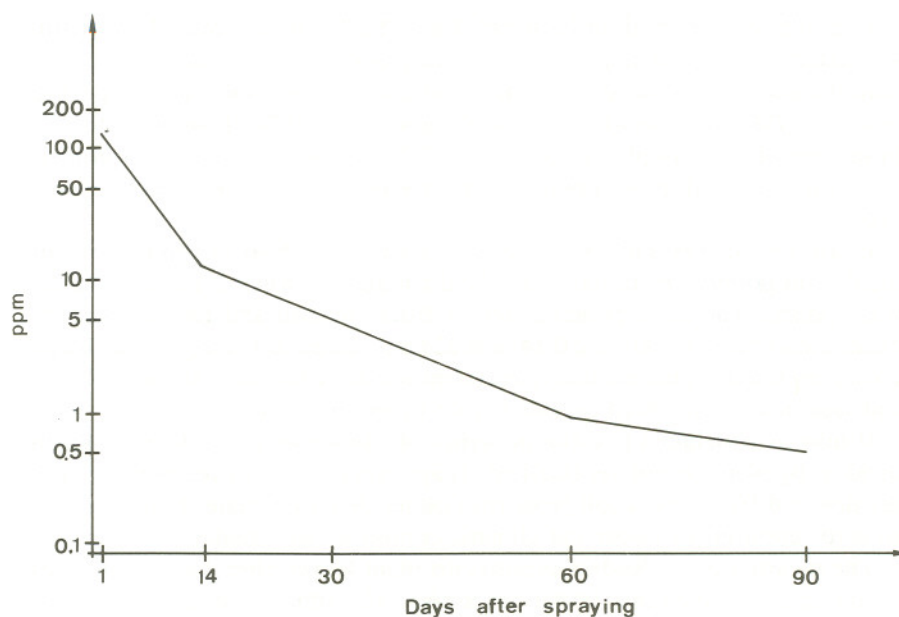


Figure 5.4.4 Disappearance of dieldrin from leaves of tree canopy in Nigeria (Koeman *et al.*, 1978). Reproduced by permission of Elsevier Applied Science Publishers Ltd

Table 5.4.1 Dieldrin content (ppm/fresh weight) in fauna after dieldrin spraying in Adamaoua, Cameroon (Müller *et al.*, 1981). Reproduced with permission of Springer-Verlag, Berlin

Species	Directly after spraying				One year after spraying			
	$\bar{X}/\bar{X}^{(1)}$	min.	max.	n ²⁾	$\bar{X}^{(1)}$	min.	max.	n ²⁾
<i>Praomys tullbergi</i> (liver) (rat)	0.37	0.00	1.20	13	0.29	0.04	0.74	3
<i>Micropteropus pusillus</i> (liver) (fruit bat)	136.00	1.48	174.81	11	0.14	0.02	0.20	3
<i>Halcyon malimbicus</i> (liver) (insectivorous bird)	4.30	2.21	4.30	8	6.52	5.44	7.70	2
<i>Nectarinia verticalis</i> (liver) (nectarivorous, insectivorous bird)	1.80	1.03	2.44	5	0.24			1
<i>Turdus pelios</i> (liver) (polyphagous bird)	0.43	0.20	0.91	8	3.00	0.00	6.00	2
<i>Dorylus</i> spp. (Formicidae) (male)	0			(ca.10)	0.15	0.14	0.15	2 (ca.15) ³⁾
<i>Lumbricidae</i> (earthworms)					0.02	0.02	0.02	2 (ca.50) ³⁾

¹⁾ \bar{X} = mean value; for $n \geq 4$ the median value \bar{X} is given

²⁾n = number of samples

³⁾In brackets: number of individuals in mixed samples

10% of the whole above-ground biomass of invertebrates was destroyed in Adamaoua in order to extinguish one disease vector, i.e. *Glossina morsitans submorsitans*. One year after treatment, the arthropod fauna of the ground surface in the gallery forest as a whole showed a significant reduction in the abundance of individuals. Although these results might indicate a weakening of the stability of the biocoenosis in the face of exogenous influences, the diversity values simultaneously gave results which indicated a complete restoration of the inner stability of the biocoenosis. For the phytophagous insects of the herbaceous and foliage layers of the gallery forest (studies made of the Macroheterocera as an example) it was illustrated that the diversity of some biocoenoses was reduced by dieldrin treatment. It could further be proved that some non-target species in the treated area were destroyed by the pesticide.

In vertebrates, no acute mortality could be established after spraying. On the basis of the chemical residue analyses in connection with the analyses of the food web, it can be stated that fruit-eating birds might be endangered in the long run. The fruit-eating bats, which in some cases showed an especially high concentration of the noxious agent directly after treatment, could be found to have strongly reduced residue values after one year and moreover did not show any negative changes in their population structure. The residue values of some insect-eating birds indicate the risk of acute as well as of long-term damage, though even one year after spraying no negative population development could be observed. On the other hand, in the selected study area, insectivorous bats and shrews could no longer be recorded.

In spite of the evidence of an extremely strong direct effect of dieldrin on non-target terrestrial organisms, both with regard to the reduction in numbers of individuals and the extirpation of some species within the treated area, the investigations did not reveal any structural or energetic changes of the gallery forest ecosystem as a whole. This statement is valid provided that the acute loss of small insectivorous mammals can be compensated rapidly from uninjured regions.

A similar study was carried out by spraying 900 g/ha active ingredient dieldrin on a Northern Guinea-type savanna zone in Nigeria (Koeman *et al.*, 1978). Before, and at various intervals after spraying, a population census was made of a number of selected bird species. Certain species of fringe forest birds, such as various flycatcher species, appeared to be very vulnerable and either ceased to be recorded or became extremely rare in the treated areas.

The occurrence of residues of a chemical in animals of high trophic levels, such as birds of prey, is often regarded as a measure of its potential for ecological magnification. Frank *et al.* (1977) analysed pectoral muscle samples of 18 species of resident Kenyan raptors of different trophic levels for the presence of dieldrin, and compared the values with reported data of birds of prey in temperate climates. Many raptors from agricultural areas contained dieldrin whereas

those from non-agricultural areas did not. While levels were generally low compared to those reported in populations of birds of prey from temperate latitudes, falcons and accipiters from highly agriculturalized areas, such as the region around Nairobi, contained residue levels of more than 2 ppm. The authors suggested that chlorinated hydrocarbon kinetics may not be the same in the tropics as in Northern latitudes inasmuch as terrestrial ecosystems seem to show higher levels than aquatic systems.

5.4.5 OCCURRENCE IN HUMAN FOOD AND HUMAN TISSUES

Müller *et al.* (1981) did not find noxious dieldrin levels in human foodstuffs one year after dieldrin application against tsetse flies in Cameroon. No residues were detected in cow's milk or wild honey, and only 0.03 ppm in beef. However, residues are expected after intentional application of the insecticide on food plants, animal feed, or on animals themselves.

Samples of wheat collected from Bombay markets in India revealed that aldrin residue levels in wheat were in the range of 0.50–0.08 ppm. Of the 18 samples contaminated with aldrin, two had residues above the tolerance limit prescribed by WHO (Krishna Murti, 1984). Aldrin residues in groundnut oil collected from the markets in two Indian districts (Lucknow and Sitapur) averaged 0.290 and 0.892 ppm respectively (Srivastava *et al.*, 1983). Twenty-five egg samples collected from Bombay markets showed a high incidence of contamination from dieldrin and aldrin, the residue levels being 0.61–1.04 ppm and 0.14–0.52 ppm (Banerji, 1979). The content of aldrin in farm eggs from Lucknow in India was 0.93 µg per egg, and in eggs from domestic hens, 0.40 µg per egg (Siddiqui and Saxena, 1983). The concentration of dieldrin and aldrin in muscles of fish from India was 0.03 ppm and 0.03–0.04 ppm respectively (Bhinge and Banerji, 1981). Average concentrations of aldrin in buffalo and goat milk were 0.041 ppm (Saxena and Siddiqui, 1982).

In Brazil, meat from cattle raised in the most developed agricultural regions of the state of Minas Gerais showed the highest residual levels. The mean quantity in the state was 0.02 mg/kg (Maia and Brant, 1980). In 32% of the samples taken from dairy products in South Africa (Luck and van Dyk, 1978), the dieldrin level (mean 0.13 mg/kg) exceeded the international maximum residue limit. The authors suggested that dieldrin is often misused, which probably is the case in other countries also.

The occurrence of pesticide residues in human food is closely related to that in human tissues. Table 5.4.2 (Hunter *et al.*, 1969) presents mean concentrations of dieldrin in adipose tissues of people of various countries, as well as daily intake estimated from these concentrations. The table reveals that concentrations in adipose tissue are lowest in India, with a mostly hot and moist climate, and in Australia, with a mostly subtropical climate, whereas they are higher for the countries in temperate climate zones. However, for Australia, higher values have

Table 5.4.2 Mean concentrations of dieldrin in human adipose tissues and estimated human intake in various countries (Hunter *et al.*, 1969). Reproduced with permission of Heldref Publications

Country	Mean concentration in adipose tissue (mg/kg)	Estimated daily intake ($\mu\text{g}/\text{person}/\text{day}$)
India	0.03	1.6*
Australia	0.05	2.7
United States	0.14	7.6*
Canada	0.16	8.6*
United Kingdom	0.23	12.4
New Zealand	0.27	14.6*

*Arithmetical mean

been reported too (0.67 ppm: Wassermann *et al.*, 1968; 0.21 ppm: Brady and Siyali, 1972). Since the residues in human fat depend on many factors, the variability of data is not a good basis for concluding that aldrin/dieldrin is less persistent in the tropics.

Table 5.4.3 shows the concentrations of dieldrin in the adipose tissue of the general population in South Africa (Wassermann *et al.*, 1970). The table indicates that factors such as sex and race exert an influence on the storage levels in a given area. Age is an important factor also. In Nigeria, dieldrin averaged between 0.002 ppm in the adipose tissue of the foetus and 0.18 ppm in the 25–44 year group (Wassermann *et al.*, 1972b). In Brazil, average dieldrin concentrations in adipose tissues were between 0.011 and 0.133 ppm (Wassermann *et al.*, 1972a); in Mexico, between 0.06 and 0.18 (Albert *et al.*, 1980); and in Uganda, between 0.021 and 0.038 (Wassermann *et al.*, 1974a). These data seem to indicate that the storage of dieldrin in these countries is low compared with other countries of Europe, North and South America, and Asia. A positive relationship between *p,p'*-DDT and dieldrin storage was also noted. This finding may be explained by a biochemical interrelationship of the two compounds in the body, the presence of a large amount of DDT interfering with the detoxification of dieldrin, resulting in its accumulation in adipose tissue (Wassermann *et al.*, 1974b).

In India, samples of placenta and accompanying fluid as well as of circulating blood were frequently found to contain aldrin and dieldrin (Saxena *et al.*, 1980a, 1980b, 1981). Breast milk samples from Lucknow (India) contained a mean level of aldrin of 0.03 ppm (Siddiqui *et al.*, 1981).

Due to insufficient information on exposure levels and living habits of the persons in question, these data cannot be interpreted in relation to climatic factors.

5.4.6 CONCLUSIONS

It may be concluded from the review of literature on the fate and effects of aldrin/dieldrin in terrestrial ecosystems of hot climates, that both these

Table 5.4.3 Concentration of dieldrin in the adipose tissue of the general population of South Africa (ppm) (Wassermann *et al.*, 1970). Reproduced with permission from the Medical Association of South Africa

Group	Mean Content
Bantu females	0.034
White females	0.047
Bantu males	0.033
White males	0.048
Females (total)	0.040
Males (total)	0.039
Bantu (total)	0.034
Whites (total)	0.047
General population	0.039

insecticides are less persistent than in temperate climates; however, in aquatic systems the difference between climates is probably even greater. Increased volatilization due to higher temperatures and to higher soil moisture content is probably a major reason for these differences; degradation is also possibly enhanced. Although accumulation in organisms and effects on ecosystems after dieldrin application do occur, birds of prey in general do not have such high residues as those in temperate climates. Residues in human food and storage in human tissues have been observed to be lower in some cases. Since the use of aldrin and dieldrin continues in developing countries, influences of climate on their fate and their effects should be investigated further.

5.4.7 REFERENCES

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