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5.7 *Fate and Undesirable Effects of Pesticides in Egypt*

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5.7.1 INTRODUCTION

An overview of the status of the pesticides used in Egypt is presented in a case study. The fate, distribution, and adverse effects of the widely used pesticides are discussed. Chlorinated hydrocarbon insecticides and structurally related derivatives are found to be highly persistent and biomagnified in the environment. However, the OP insecticide Leptophos was shown to be quite persistent and liable to be stored in lipoid tissues. In addition, the hazards resulting from acute, semi-chronic toxicity of the insecticides used are reported.

5.7.2 ECOLOGICAL FACTORS AFFECTING AGRICULTURAL ACTIVITIES IN EGYPT

Egypt is a semi-arid country where the six million acres (2.4 million hectares) of arable land lie in the Nile River delta and narrow valley. This irrigated land is only 5–7% of the total area of the country, while the rest is a mere desert. Additional agricultural activities in the vast deserts are limited to some oases depending on underground water sources, and the only rain helpful for agriculture is confined to the northwestern coast along the Mediterranean, where only about 100 000 acres (40 000 hectares) are cultivated.

The annual River Nile input is 60 billion cubic metres. It is estimated that above one-third of that total flows to the Mediterranean Sea. Another third is used for irrigation, and the rest is lost in vaporization, runoff, and leaching down to the water table.

The Nile water originates from the African plateau and crosses the following eight countries before reaching Egyptian territory: Sudan, Ethiopia, Uganda, Tanzania, Kenya, Zaire, Rwanda and Burundi. While flowing through these countries, the Nile River is loaded with various types of pesticides and many other contaminants. Thus it arrives in Egypt after already being polluted with different pollutants, including the persistent chlorinated pesticides.

The majority of the 50 million inhabitants of Egypt live in crowded cities and villages along the narrow green strip of land beside the River Nile and its north delta around the capital, Cairo. The Nile watercourse is thus used for irrigation and transportation, as well as for industrial and recreational activities. The river is also partially used for disposal of some agricultural waste water, and some industrial wastes. In this densely populated and limited area, more than 30 000 metric tonnes of formulated pesticides are imported and used annually. More than 70% of these pesticides are insecticides used to control cotton insect pests, especially the leaf and bollworms. This programme is important to protect cotton, which is the main Egyptian cash crop.

To control these insect pests, aerial spraying is used to apply more than 75% of the pesticides, a method which is particularly hazardous to the inhabitants and non-target organisms. Such congestion makes it difficult to implement an evacuation or re-entry programme. Moreover, herbicides, fungicides, fertilizers, molluscicides, food additives, and synthetic dyes and other chemical pollutants are present in the Egyptian environment.

The recent agricultural development plans adopt the horizontal and vertical intensified condensed agriculture, which might require the use of more pesticides and other agrochemicals and which thus might magnify the spectrum and magnitude of environmental pollution and hazards of such chemical agents.

5.7.3 STATUS OF PESTICIDES USED IN EGYPT

In Table 5.7.1, the area of field crops treated with pesticides during the period 1951–1981 is indicated. The area treated to control cotton bollworms was higher than expected because it shows 3–4 sprays per season in the area of cotton

Table 5.7.1 Area of field crops treated with pesticides during the period 1951–1981 in Egypt. Source: Egyptian Ministry of Agriculture Records. Reproduced with permission

	Area ($\times 10^2$ acres) (1 acre = 0.4 hectare)			
Crop Pests	1951	1961	1971	1981
Cotton leafworm	200	1100	1400	300
Cotton bollworm	–	1400	3980	4500
Cotton thrips	2	104	420	200
Cotton spidermite	1	111	171	16
Corn borers	–	300	437	36
Rice pests	–	–	200	500
Vegetable pests	–	–	50	250
Fruit-tree pests	–	100	100	200
Household insects (in tons)	1	10	20	50

Table 5.7.2 Total active ingredient (a.i.) insecticides used in Egyptian agriculture during the 30 year period 1955–1985. Source: Ministry of Agriculture records. Reproduced with permission

Compound	Total a.i. (metric tonnes)	Years of consumption
Toxaphene	54,000	1955–1961
Endrin	10,500	1961–1981
DDT	13,500	1952–1971
Lindane	11,300	1952–1978
Carbaryl	21,000	1961–1978
Trichlorfos	6,500	1961–1970
Monocrotophos	8,300	1967–1978
Leptophos	5,500	1968–1978
Chlorpyriphos	13,500	1969–1985
Phosfolan	5,500	1968–1983
Mephosfolan	7,000	1968–1983
Methamidophos/Azinphos-Me	4,500	1970–1979
Triazophos	5,500	1977–1985
Profenofos	6,000	1977–1985
Methomyl	6,500	1975–1985
Fenvalerate	6,500	1976–1985
Cypermethrin	4,300	1976–1985
Deltamethrin	3,400	1976–1985

cultivation, which is on average 1.2–1.5 million acres (0.4–0.6 million hectares) per year.

In Table 5.7.2, the types and amounts of insecticides used on cotton during the last 30 years are shown. Toxaphene, which had been used extensively since 1955, was stopped in 1961 after its failure due to the build-up of resistance in the cotton leafworm, *Spodoptera littoralis*, leading to an outbreak of this insect which resulted in 50% loss of the cotton yield in that season. Carbaryl and trichlorfos were introduced to replace toxaphene; however they also lost their effectiveness after 4–5 years due to the problem of resistance. DDT/endrin, DDT/lindane and methyl parathion combinations were attempted but were soon found to be ineffective.

From 1967, monocrotophos was widely used in cotton in four sprays per season, but this has suffered since 1973, due to resistance. This opened the way for the introduction of compounds which were not yet registered in the producing countries. Leptophos, the OP phosphothionate ester, was shown to cause the adverse effect of delayed neuropathy in humans and livestock. The 1971 water buffalo episode is quite famous. Then chlorpyrifos, triazophos, profenofos, methomyl, and synthetic pyrethroids were recently introduced.

In Table 5.7.3, the generally used types of pesticides in Egyptian agriculture are listed.

Table 5.7.3 Types of pesticides imported into Egypt in 1985. Source: Ministry of Agriculture Records. Reproduced with permission

Item	Amount in tonnes of formulated materials
Organophosphorus insecticides	1000
Carbamate insecticides	550
Synthetic pyrethroids insecticides	800
Chlordane	50
Agricultural spray oils	5000
Photoxin	100
Acaricide (Kelthane)	500
Rodenticides	9000
Sulphur	20 000
Fungicides	4500
Herbicides	3500

Table 5.7.4 Concentration (ppb) of organochlorine insecticides in soil samples at El-Minia, El-Behera, and Dakahlieh Provinces, August, 1979

Samples/ location	Lindane	Endrin	DDT	DDD	DDE	Chlordane
El-Minia 1	0.15	0.16	1.40	1.20	n.d.	0.25
El-Minia 2	0.24	0.19	1.30	1.10	n.d.	0.30
El-Behera 1	0.70	0.30	0.38	0.56	n.d.	n.d.
El-Behera 2	0.50	0.48	0.40	0.84	n.d.	n.d.
Dakahlieh 1	1.20	1.00	1.54	1.34	n.d.	0.20
Dakahlieh 2	1.25	1.50	1.70	1.50	n.d.	0.24

5.7.4 DATA DEALING WITH FATE AND DEGRADATION OF PESTICIDES IN THE EGYPTIAN ENVIRONMENT

The chlorinated hydrocarbon insecticides were shown to be highly persistent in the soil, sediments, and food-chain organisms. They are also stored in human adipose tissues. The concentration of organochlorine insecticides was determined in soil samples from the three Egyptian Governorates: El-Minia (middle of Egypt); El-Behera (northwest of the delta); and Dakahlieh (northeast), during 1979 by Aly and Badawy (1981). The data are shown in Tables 5.7.4 and 5.7.5. Generally, the levels of chlorinated insecticides were higher in the Dakahlieh followed by El-Behera and then El-Minia. This order is parallel to the actual frequencies of utilization of the insecticides. The relatively high levels of chlorinated insecticides in soil years after cessation of application reflect the high persistence and the long half-life of such compounds in the soil.

The chlorinated insecticides were monitored by El-Sebae and Abo-Elamayem (1978) in municipal water in Alexandria City (Table 5.7.6). Data indicated that classical water treatment might reduce the organochlorine insecticide levels, but

Table 5.7.5 Concentration (ppb) of organochlorine insecticides in soil samples at El-Minia, El-Behera, and Dakahlieh Provinces, October, 1979

Samples location	Lindane	Endrin	DDT	DDD	DDE	Chlordane
El-Minia 1	0.15	0.15	1.30	1.32	n.d.	0.30
El-Minia 2	0.20	0.22	1.35	1.25	n.d.	0.42
El-Behera 1	0.52	0.25	0.40	0.60	n.d.	n.d.
El-Behera 2	0.55	0.40	0.45	0.90	n.d.	n.d.
Dakahlieh 1	1.15	1.10	1.60	1.50	n.d.	0.22
Dakahlieh 2	1.20	1.30	1.40	1.38	n.d.	0.34

Table 5.7.6 Chlorinated pesticides in different water sources in Alexandria City

	Concentration (ppb)			
Pesticide detected	Raw water Mahmoudia	Treated water El-Soyef plant	Tap water	Waste water of slaughter-house
BHC*	0.39	N.D.†	0.10	0.19
Lindane	0.34	0.19	0.29	0.63
Heptachlor	0.70	0.10	0.12	0.19
p,p′-DDT	0.65	0.47	0.47	0.95
O,p′-DDT	0.95	N.D.	0.95	0.25

*Calculated as lindane
†Not detected

Table 5.7.7 Chlorinated pesticides in water and sediment samples at Lake Mariut, Alexandria

	Mean concentrations (ppb)			
	Lindane		p,p′-DDT	
Lake stations	Water	Sediment	Water	Sediment
I	2.06	142.8	3.85	982
II	2.10	74.7	2.54	512
III	1.93	61.6	2.79	715
IV	1.65	120.3	2.80	920
V	1.75	92.2	5.35	796
VI	1.75	52.8	4.31	910
VII	1.79	54.3	6.39	972
VIII	2.76	114.5	4.86	318

that there is still an appreciable level of these pollutants in the tap drinking water. The chlorinated insecticides were also detected in sediments of the northern brackish lakes, such as Lake Mariut near Alexandria, as shown in Table 5.7.7 (Abo-Elamayem *et al.*, 1979). Similar data were reported by Askar (1980) in

Brullus Lake in the northern part of the Delta. Storage and bioaccumulation of these chlorinated insecticides were shown by levels more than 100-fold higher in sediments and fish than in water. Due to the known long half-lives of these insecticides, they are expected to last for several years to come and to continue to be one of the environmental stresses.

Recently, Ernst *et al.* (1983) reported that organochlorine compounds were monitored in some marine aquatic organisms from the Alexandria area. DDT and its degradation products, gamma-BHC, alpha-BHC, dieldrin, and PCBs, were the major detected compounds. The results indicated that the western coast of Alexandria is polluted with organochlorine compounds. Moving towards the east at Rosetta, the levels of PCBs decrease because of the absence of industrial discharges. Generally, the recorded levels are in the range of the tolerated maximum residue limits. However, these low levels still represent a potential hazard as sources for continuous bioaccumulation and biomagnification in the food chain.

Similar data in fish samples were reported by Macklad *et al.* (1984a), concerning Lake Maryout and Alexandria Hydrodrome. Macklad *et al.* (1984b) detected the chlorinated compounds in different fish samples from two sampling sites at Edku Lake and Abu Quir Bay. BHC, DDE, DDD, endrin, DDT, and polychlorinated biphenyls were the major ones recorded. DDE was the major detected DDT metabolite in fish samples. The ratio of alpha to gamma-BHC isomers in different fish species from Edku Lake was higher than Abu Quir fish samples, suggesting older residues in Edku Lake. The level of chlorinated pesticides in *Tilapia* fish was positively correlated with fat tissue content. PCBs, such as Arochlor 1260, were higher in Abu Quir samples, where most industrial wastes are discharged.

Organophosphorus, carbamate, and synthetic pyrethroid insecticides replaced the organochlorine insecticides. Othman *et al.* (1984) estimated the half-life of residues of a number of these recently introduced insecticides on tomato. These

Table 5.7.8 Residue half-lives of certain insecticides on cabbage and tomato

Insecticide	Plant part	Half-life in days
Flucythrinate	Cabbage leaves	4.0
	Tomato leaves	5.9
	Tomato fruits	3.3
Cypermethrin	Cabbage leaves	13.1
	Tomato leaves	7.3
	Tomato fruits	11.6
Dimethoate	Cabbage leaves	2.95
	Tomato leaves	3.40
	Tomato fruits	2.40
Methomyl	Cabbage leaves	1.40
	Tomato leaves	1.30
	Tomato fruits	0.52

values are shown in Table 5.7.8. Methomyl, the oxime carbamate insecticide, had the shortest half-life, followed by dimethoate, flucythrinate, and cypermethrin.

The type of soil affects the adsorption, leaching, or translocation rate of pesticides. El-Sebae *et al.* (1969) demonstrated the variation in the characteristics of three Egyptian soil types as shown in Table 5.7.9. They also showed that the initial adsorption of the herbicide Dalapon on the three soil types differs widely, being higher on the sandy than the silty type, while the muck clay type retained the lowest level of the herbicide (Table 5.7.10). However, the dissipation rate was higher in the sandy soil due to the high loss through evaporation and leaching. The higher organic matter content and compactness in heavy soil types account for the greater ability of these two types to hold the residues of Dalapon for longer intervals.

Riskallah *et al.* (1979) studied the stability of Leptophos in water samples from different sources in the Egyptian environment. Leptophos proved to be a rather stable compound. After four months a considerable amount of this compound still remained unchanged in different water samples. The same trend was reproduced in samples from the River Nile irrigation and drainage water samples. This high stability was also shown on sprayed plant foliage even under direct sunlight. Thus Leptophos can be considered one of the most persistent OP insecticides in the environment.

El-Zorgani (1980) recorded the DDT content of samples of seven fish species taken at Wadi Halfa on Lake Nubia at the border between Sudan and Egypt. The results are shown in Table 5.7.11. p,p′-DDE found in all ten samples analysed was at relatively high levels, confirming contamination of fish samples with levels of DDT significantly higher than the maximum permissible levels. Such high pollution with DDT was attributed to the continued use of DDT on cotton fields in the Gezera project in central Sudan. DDT was banned in Sudan in 1981.

Table 5.7.9 Characteristics of three soil types

Soil Type	pH	Water saturation (%)	Number of bacteria per gm	Organic matter (%)
Sandy	7.8	18.9	50 000	0.09
Silty	7.1	38.8	112 000	0.70
Clay	8.0	60.7	211 000	0.75

Table 5.7.10 Persistence of Dalapon in three soil types

	ppm after shortage for			
Soil type	0 days	7 days	14 days	21 days
Sandy	29.95	17.5	3.5	0.5
Silty	27.30	20.5	15.5	8.0
Clay	24.85	23.0	17.5	12.0

5.7.5 ECOTOXICOLOGICAL FACTORS AFFECTING PERSISTENCE AND DISTRIBUTION OF PESTICIDES

Plant foliage differs widely in its wettability according to variations in plant species, age, plant part, and upper or lower surface of plant leaves. Data in Table 5.7.12 demonstrate such differentiation between four plant species: maize, broad bean, cotton, and squash (El-Sebae *et al.*, 1982). Such variation was found to affect the deposit toxicity of the two insecticides fenvalerate and tetrachlorvinphos in E.C. formulations against the cotton leafworm (*Spodoptera littoralis*) larvae (Table 5.7.13). Squash, which was shown in Table 5.7.12 to be readily wetted and to have the least thick cuticle, was the most susceptible at the same rate of application due to the higher initial deposit.

Temperature is one of the main extrinsic factors which has a continuous impact on chemical and biological processes in the environment. Increased temperature in tropical and semi-tropical areas is expected to increase the evaporation of the pesticide residues under humid conditions.

Table 5.7.14 presents the physico-chemical properties of some widely used insecticides, including the partition coefficient, the hydrolytic half-life, water solubility and vapour pressure. Such vapours can be transported by wind movement and then reprecipitated with rain to areas which might never have

Table 5.7.11 Residues of organochlorine insecticides in some fishes from Lake Nubia

	Residue content (ppb) μg/kg		
Type	p,p′-DDE	p,p′-DDT	Total as p,p′-DDT*
Barbus bynni (Forsk.)			
1–Muscle	1.0	5.0	6.0
2–Muscle	107.0		119.0
3–Muscle	39.0		43.0
Hydrocynus forskalii (Cuv.)			
1–Muscle	3.0	5.0	8.0
2–Muscle	153.0	14.0	184.0
Labeo coubie (Rupp.)			
1–Muscle	21.0		23.0
Labeo niloticus (Forsk.)			
1–Liver	4.0		4.0
2–Liver	2.0		2.0
3–Liver	12.0		13.0
Lates niloticus (Linn.)			
1–Muscle	6.0		7.0

* DDE content was multiplied by 1.11

Table 5.7.12 Plant species variation in wettability at different leaf development stages

Plant species	1st-stage leaves Upper	1st-stage leaves Lower	4th-stage leaves Upper	4th-stage leaves Lower
	% leaf area wetted			
Maize	8	9	28	47
Broad bean	12	27	38	69
Cotton	71	78	36	39
Squash	72	76	83	84
	Thickness of cuticular layer (μm)			
Maize	12.6	10.4	9.3	6.2
Broad bean	8.9	5.6	5.3	3.8
Cotton	4.7	2.8	2.5	1.8
Squash	2.1	1.2	0.7	0.3

Table 5.7.13 Plant species variation in deposit toxicity of fenvalerate and Tetrachlorvinphos to cotton leafworm (by dipping technique)

	LC50 (ppm)	
Plant species	Phenvalerate	Tetrachlorvinphos
Maize	21	920
Broad bean	19	850
Cotton	13.5	730
Squash	11.0	600

Table 5.7.14 Physico-chemical properties of some widely used insecticides

Pesticide	Partition coefficient (log P) octanol/water	Half-life* (hours)	Water solubility (ppm at 25°C)	Vapour pressure (mm Hg at 15°C)
p,p′-DDT	6.19	–	0.0012	1.9×10^{-7}
Leptophos	6.31	22.8	0.0047	–
Ronnel	4.95	6.7	1.08	8×10^{-4}
Chlorpyriphos	5.08	21.3	2.00	1.87×10^{-5}
Chlorpyriphos-methyl	4.31	–	4.00	4.22×10^{-5}
Parathion	3.82	37.3	11.9	3.78×10^{-5}
Methyl parathion	2.97	6.9	55.00	9.7×10^{-6}
Fenitrothion	3.38	–	30.00	5.4×10^{-5}
Bromophos	5.81	36.6	2.00	4.6×10^{-5}
Me bromophos	5.16	7.1	40.00	1.3×10^{-4}
Dimethoate	−1.71	10.4	25,000.0	8.5×10^{-6}
EPN	4.68	40.9	insoluble	3.0×10^{-4}

*Half-life in hours is the hydrolysis rate at 72°C in ethanol at pH 6.0 buffer solution.

used such an insecticide. This might explain the cyclodiene organochlorine insecticides detected in closed lakes in Sweden and some other European countries where they have never been used.

Temperature variation might affect the level of toxicity of the same compound to the same insect. This is called the temperature coefficient for each compound. Most of the insecticides have positive temperature coefficients, while DDT and some synthetic pyrethroids are generally of negative temperature coefficient.

Increased relative humidity favours insecticidal toxicity (Kamel and El-Sebae, 1968). Lipoid solubility in terms of partition coefficient (Table 5.7.14) reflects the potential of bioaccumulation and biomagnification of persistent insecticides. The data showed that Leptophos is more lipoid soluble than p,p′-DDT.

Photolysis is one of the degradation processes and is intensified under subtropical arid and semi-arid areas. Recently El-Sebae *et al.* (1983) reported that photoperiodism affects fish susceptibility to insecticides. The toxicity of cypermethrin and fenvalerate to mosquito fish (*Gambusia affinis*) was significantly increased under the 12 hr darkness and 12 hr light rotation when compared with the condition of continuous darkness. It was also found that at 0900 fish were more susceptible to poisoning than at 2100, due to circadian rhythmic response effects.

5.7.6 ADVERSE AND HAZARDOUS EFFECTS OF PESTICIDES IN EGYPT

Hegazi *et al.* (1979) studied the effect of the application of a group of pesticides (aldicarb, pendimethalin, dinoseb, chlorpyrifos and simazine) on nitrogenase activity in Giza clay-loam soil under maize cultivation near Cairo. All these pesticides showed different inhibitory effects and these effects were increased with higher doses and longer incubation periods.

Carbamate and organophosphorus insecticides were found to cause harmful inhibition of soil dehydrogenase activity (Khalifa *et al.*, 1980). Similar unfavourable side-effects of other pesticides on different soil enzymes were reported.

Cole *et al.* (1976) demonstrated that sub-surface application of aldrin resulted in reduction of the corn plant's height due to its phytotoxicity. Other compounds and solvents are known to be phytotoxic. Edwards and Thompson (1973) indicated that pesticides in the soil affect its content of non-target and beneficial organisms, including earthworms, collembolans, and insect larvae. This leads to deleterious effects on the texture and fertility of the soil. Organochlorine insecticides tend to accumulate to 9-fold in earthworms and 20-fold in soil snails (Gish, 1970). Such soil fauna can be used as indicators for monitoring levels and effects of pesticides and their degradation products in the soil.

El-Sebae *et al.* (1978) were able to minimize the acute toxicity of methomyl and zinc phosphide through the microcapsulation formulations using sustained gelatine capsule walls.

Delayed neuropathy is one of the adverse effects caused by some organophosphorus insecticides, particularly of the phosphonate type. El-Sebae *et al.* (1977, 1979, 1981) proved that Leptophos, EPN, trichloronate, salithion, and cyanophenphos are delayed neurotoxicants. Evidence was given clinically and biochemically. This effect is irreversible and there is no antidote for their application. Recently, methamidophos, trichlorfon, and DDVP were found to cause delayed neuropathy in man.

Cytotoxic effects, including mutagenesis, carcinogenesis, and teratogenesis, were reported for a number of pesticides. The list in Table 5.7.15 indicates these health hazards (El-Sebae, 1985).

El-Mofty *et al.* (1981) proved that the bilharzia snail molluscicide, niclosamide, is carcinogenic to amphibian Egyptian toads. Raymond and Alexander (1976) indicated that nitrosoamines can be formed in the soil from the reaction between some carbamates and nitrites. Nitrosamines can be translocated to edible plants.

El-Sebae (1985) found also that the response of exposed workers to pesticide poisoning differs widely, depending upon their blood group type. Such wide genetical variation should be taken into consideration when applying a safety factor in setting acceptable daily intakes of such pesticides and related toxic derivatives.

Table 5.7.15 Cytotoxic hazards of pesticides used in Egypt

Compound	Type of cytotoxic hazard expected
Amitraz	Oncogenicity
Azinphos-methyl*	Oncogenicity
Benomyl	Teratogenicity
BHC	Oncogenicity
Captan*	Teratogenicity
Carbaryl	Fetotoxicity
Chlorbenzilate	Oncogenicity
Chlordane	Oncogenicity
Chlordimeform	Oncogenicity
Dimethoate	Oncogenicity
Dichlorovos	Fetotoxicity
Endrin	Oncogenicity
Monuron	Oncogenicity
Niclosamide	Oncogenicity
Permethrin	Oncogenicity
Propanil	Oncogenicity
Trichlorofon	Oncogenicity
Trifluralin*	Oncogenicity
Toxaphene	Oncogenicity
Thiodicarb	Oncogenicity

*Waters *et al.* (1980). Reproduced with permission

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